PLAIN AND REINFORCED CONCRETE CONSTRUCTION

Plain and Reinforced Concrete Construction

CEMENT AND AGGREGATES, PROPORTIONING AND MIXING CONCRETE, CONVEYING AND DEPOSITING CONCRETE FORMS, STEEL REINFORCEMENT, EXAMPLES OF REINFORCED-CONCRETE CONSTRUCTION, CONCRETE-BLOCK CONSTRUCTION

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PREFACE

Plain- and reinforced-concrete construction has had a remarkable development during the last two decades. Engineers and architects have come to appreciate its lasting and fire-safe qualities, and are employing it widely. In recent years many sanitary factories, fireproof office buildings, comfortable homes, and various other structures have been built of reinforced concrete, and thousands of miles of durable concrete roads have been laid. All indications point to even more extensive employment of concrete in the future.

The rapid growth of the concrete industry is best appreciated when one realizes that the number of cubic yards of concrete placed in this country was only about one-quarter million in 1890, about six million in 1900, and almost one hundred million in 1923. This means that the cost of concrete placed in 1923 was over one billion dollars. As the concrete industry develops there is a growing need for education concerning it. Such education is vital not only to the engineer and architect, but also to all engaged in the concrete field or who contemplate entering it.

In this volume are presented, in a clear and concise manner, the fundamentals of concrete and reinforced concrete as applied to building construction. The proper methods of proportioning, mixing, and placing concrete are explained; the ways of building forms for concrete and reinforced-concrete structures are treated; the various types of reinforcement used in reinforced concrete are described, and their applications discussed and illustrated. In addition, examples of reinforced-concrete and concrete-block construction are given. The field covered by the volume is very large in scope, and of necessity the style used is rather brief, but all salient features of the subject are carefully treated so as to answer the practical needs of men who are interested in concrete construction and have not the time for exhaustive study.

Much of the information contained in this volume was obtained from Mr. H. Colin Campbell, Manager, Advertising and Publication Bureau, Portland Cement Association.

W. S. LOWNDES, Editor.

CONCRETE CONSTRUCTION

MATERIALS AND METHODS

GENERAL EXPLANATIONS

1. Concrete is a mixture of cement, water, and sand, with broken stone, gravel, or cinders. When thoroughly mixed in the proper proportions and allowed to stand for a few days it becomes a hard rock-like material.

When freshly mixed it can be poured into molds or forms and will harden and take the shape of the molds. Hence, walls, columns, girders, and beams can be made by pouring concrete into properly shaped forms and allowing the concrete to harden, after which the forms may be removed.

2. Cement is a finely ground powder that will remain inactive while kept dry, but which, when mixed with water and allowed to stand for a short time, forms a hard stone-like mass.

Cement when mixed with sand and water in proper proportions forms a mortar. The cement, in hardening, binds together the particles of sand and forms a hard substance. The cement also adheres to bricks and stones between which mortar is laid, thus binding them together to make a solid wall.

3. If pieces of stone, gravel, slag, or cinders are mixed with mortar, **concrete** is formed. Its strength and usefulness depend upon the strength and proportions of the various ingredients used. In both mortar and concrete, the greater the proportion of cement that is used (within the limits of the

proportions commonly used in mortar), the stronger the resulting product will be.

4. Aggregates.—The stone, gravel, slag, and cinders entering into the composition of concrete are called *aggregates*, or *coarse aggregates*. Sand is also considered as an aggregate and is referred to as a *fine aggregate*.

5. Mixing.—The process of mixing concrete is a mechanical one and can be done by hand labor or somewhat more efficiently by machines called mixers. The process of mixing will be described later.

CEMENT

6. Description of Cement.—The cement here referred to is *Portland hydraulic cement*. It is manufactured by mixing together limestone and clay, grinding them to a powder; burning at a high temperature in a kiln; and grinding the resulting clinkers into an impalpable powder. Cement and its properties are described in the Section *Limes, Cements, and Mortars*.

7. Forms of Package.—Cement is sometimes sold in barrels, but is more generally sold in bags, as the bags are smaller than barrels and are consequently more easily handled. A bag contains about 94 lbs. and in practice is counted as 1 cu. ft. in volume. A barrel contains the equivalent of 4 bags.

8. Storing of Cement.—When cement is received on a job it should be carefully stored in a suitable shed or house until used. Such a shed should be constructed with a floor raised above the ground and formed of two thicknesses of flooring boards with a layer of waterproof paper between them. The walls and roof should also be made waterproof.

The bags of cement should be stored in the shed so that there will be a free circulation of air that will prevent dampness. The bags belonging to each shipment of cement should be piled separately so that their identity shall not be lost.

9. Testing of Cement.—It is customary for manufacturers to test the cement in each of their storage bins, and the

results of the tests of the cement from the bin from which shipment is made can be obtained by the contractor or architect if he so desires.

It is advisable, however, especially where the work in which the cement is to be used is large or important, to test the cement as it arrives at the building. This testing is best done by firms that make a practice of doing such work, who have special testing laboratories, and are generally found in all large cities.

10. When such a firm is engaged to test the cement for a building it sends a representative to the car or place where the cement is delivered and the representative secures samples of the cement in every shipment, marks the packages for identification and, if the shipments are to remain on the railroad car until examined, seals the car. The samples are taken to the laboratory, tests are made and the results compared with the standard requirements for cement as laid down by the American Society for Testing Materials. The results of the tests are formulated in reports which show the results in comparison with the standard requirements.

11. Laboratory Report.—A sample laboratory report is shown in Fig. 1. This report is made by the Pittsburgh Testing Laboratory, of Pittsburgh, Pa., on cement that was shipped for use in the construction of a General Warehouse No. 2, and was delivered at the site in railroad cars.

The report shows the results of a 7-day test and a 28-day test. The 7-day test had been previously reported but is incorporated in this report.

12. In the first vertical column are shown in larger type the required tests. At the right of the heading Laboratory Numbers is printed in smaller type Standard Specifications, Jan. 1, 1919. This indicates the date of the latest specifications prepared by the American Society for Testing Materials. Below this are the standard requirements as they relate to the different tests. The marks Pg 1578-W, Pg 1578-X, etc. at the tops of the second, third, fourth, and fifth columns are the

20M 7-19

PITTSBURGH TESTING LABORATORY

FORM 182

PITTSBURGH, PA.

51st ..28 Day.. REPORT OF TESTS OF CEMENT P. T. L. Order No. 1707

File No. 2708.3

To Smith & Jones Concrete Construction Co.,

Pittsburgh, Pa.

Cement from Aztec Portland Cement Co.,

For General Warehouse No. 2 Order No. E 886

Sample from Car at plant by P.T.L. Inspector Date Tested Nov. 27, '19

LABORATORY NUMBERS	Standard Specifications Jan. 1, 1919	Pg 1578-W	Pg 1578-X	Pg 1578-Y	Pg 1578-Z
TENSILE STRENGTH		230	264	252	238
1 to 3 Ottawa Sand		246	272	260	240
		220	282	246	238
Average 7 Days	200 lb.	232	273	253	238
TENSILE STRENGTH		366	363	370	344
1 to 3 Ottawa Sand		376	372	376	343
		360	351	363	339
Average 28 Days	300 lb.	367	362	370	342

TIME OF SETTING		Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes
Initial—Gillmore Needle	Not less than 60 minutes	2	30	2	10	3	00	2	55
Final	Not more than 10 hours	5	00	4	50	6	00	6	10

FINENESS					
Retained on No. 200 Sieve	22 per cent.	17.5	18.0	17.0	18.5
CONSTANCY OF VOLUME					
Moist Air 24 hrs. Steam 5 hrs.	Firm Hard	OK	OK	OK	OK
SHIPMENT Date		10-25-19	10-25-19	10-25-19	10-25-19
Car Initials		C.N.&W.	U. P.	A.C.L.	N.S.
Car Numbers		52478	73951	43421	20696
P. T. L. Seal Numbers		195994 A	195984 A	195942 A	195983 A
" " "		195989 A	195960 A	195938 A	195938 A
No. of Barrels in Car		231	289	173	173

3 Copies issued to Smith & Jones Concrete Construction Co from Pgh. Office

No. of bbls. on order 255,000

No. bbls. shipped this date 866

Total No. bbls. shipped to date 86,004

This Cement MEETS the requirements of the specifications

PITTSBURGH TESTING LABORATORY

Frank Lak, Tester.

P. J. Freeman

ENGINEER OF TESTS

FIG. 1

laboratory marks used to identify the samples of cement taken from the different cars. Samples are taken from a number of packages in each car and a sufficient amount of cement is taken so that several tests can be made.

13. In the second, third, fourth, and fifth columns at the bottom of the report are given the dates of shipment, the initials and numbers of the railroad cars, the Pittsburgh Testing Laboratory's seal numbers, and the number of barrels of cement in each car.

The seal numbers are the numbers on the seals that are placed on the two doors of each car after the laboratory inspector has taken his samples. If these seals are broken or missing the testing company will not guarantee that the cement in the cars is the same as that they have tested.

14. Under the headings Tensile Strength, the note "1 to 3 Ottawa Sand" signifies that the samples of cement were mixed with Ottawa sand, in proportions of one part of cement to three parts of sand. The Ottawa sand is obtained in Ottawa, Ill., and is accepted as a standard so as to insure uniformity in preparing samples for testing purposes. The sand is selected so that its particles will pass through a sieve having 20 meshes to the linear inch or 400 openings to the square inch and will not pass through a sieve having 30 meshes to the linear inch or 900 openings to the square inch.

The results of the tests for tensile strength are given for samples that have hardened or set for 7 days. In the second column are shown the results of tests of three samples marked Pg 1578-W. These results are 230, 246, and 220. These are the strengths, in pounds per square inch, of the samples tested. The fourth figure, 232, is the average strength of the three samples. The requirements of the standard specifications are 200 pounds per square inch. These tests are therefore satisfactory.

The tests of the 28-day-old specimens show an average strength of 367 pounds, whereas the standard specifications call for only 300 pounds. This test is also satisfactory.

15. The standard specifications require that the cement shall gain its initial set in not less than 60 minutes and its final set in not more than 10 hours. By noting the results given for the various samples they will be seen to have passed this test satisfactorily. The Gillmore needle is a laboratory device for testing cement and will not be described here.

16. The fineness of cement is measured by sieves. The standard specification requires that not more than 22 per cent. of the cement be retained on a sieve having 200 meshes to the linear inch or 40,000 meshes to the square inch. All the samples have passed through the standard sieve leaving less than 22 per cent. on the sieve and are sufficiently fine.

17. In the constancy of volume test it is required that after a specimen has been mixed with water and exposed to moist air for 24 hours and steam for 5 hours it shall be firm and hard. The O. K. in the report indicates that the samples have met this test successfully.

The report shows that the cement in the shipment has successfully met the requirements of the Standard Specifications and this is testified to by the signatures of the tester and the engineer of tests. This is accepted by the architect as evidence that the cement is satisfactory.

AGGREGATES

18. Kinds of Aggregates.—The materials most commonly used as aggregates are sand, stone, gravel, and slag. Sand and gravel are usually obtained from natural deposits, while the rock aggregate is obtained by crushing masses of rock that are too large to be used in the concrete.

These materials must be screened or graded. By grading is meant separating the particles into various sizes. These various sizes are mixed together again, when mixing the concrete, the proper proportions of the different sizes being used so as to make the most compact mixture.

When the particles of stone are $\frac{1}{4}$ inch or less in size they are considered as sand.

19. Sand.—It is usually required that sand for concrete shall be sharp, coarse, and clean. It is not, however, so essential that the sand be sharp but it must be clean and consist of particles most of which are coarse, or about $\frac{1}{4}$ inch in diameter. Sand is clean when it is free from foreign substances such as clay, loam, and vegetable matter. Clay and loam can be removed from the sand by washing. Sand containing vegetable matter should not be used.

If there is any doubt about the suitability of a given sand it can be examined at the testing laboratories, where specimens of the proposed sand mixed with cement and standard sand mixed with cement can be tested and compared. Good building sand will give as great, and in most cases greater, strength than Ottawa sand.

20. Stone.—It is also important that the stone be clean and of the proper size and kind. If the stones are mixed with dirt or other foreign substances they can be washed. The stone, as well as the sand, should be kept clean in suitable wooden bins from which it may be taken as needed. On small jobs, however, this may be too expensive, and a wooden platform laid on the ground may be used instead.

21. Maximum Size of Stone Aggregates.—It is very important that stones of the proper size be used. The sizes of most of the stones used in concrete should be as large as possible consistent with the character of the work. These should be mixed with a proper selection of smaller stones, to fill in the voids. For large masses of concrete, stones as large as two or three inches in their greatest diameter may be used; for reinforced concrete, stones one inch in diameter are as large as can conveniently be used. For concrete blocks, very small stones are sometimes used, but sometimes they are omitted, as the blocks are generally made hollow and with thin shells and webs that are not thick enough to accommodate large pieces of aggregate.

When the dimensions of the concrete work are very large, stones of considerable size are often bedded in the concrete with the object of saving cement, sand, and labor in mixing

TABLE I

QUANTITIES OF INGREDIENTS FOR CONCRETE OF VARIOUS PROPORTIONS

Proportion of Ingredients			Ingredients Required for 1 Cubic Yard of Rammed Concrete											
			Stone, 1 Inch and Under—Dust Screened Out			Stone, 2½ Inches and Under—Dust Screened Out			Stone, 2½ Inches—With Most Small Stone Screened Out			Gravel, ¾ Inch and Under		
Cement	Sand	Stone	Cement Barrels	Sand Cubic Yard	Stone Cubic Yard	Cement Barrels	Sand Cubic Yard	Stone Cubic Yards	Cement Barrels	Sand Cubic Yard	Stone Cubic Yards	Cement Barrels	Sand Cubic Yard	Gravel Cubic Yard
1	1.0	2.0	2.57	.39	.78	2.63	.40	.80	2.72	.41	.83	2.30	.35	.74
1	1.0	2.5	2.29	.35	.88	2.34	.36	.89	2.41	.37	.92	2.10	.32	.80
1	1.0	3.0	2.06	.31	.94	2.10	.32	.96	2.16	.33	.98	1.89	.29	.86
1	1.0	3.5	1.84	.28	.98	1.88	.29	1.00	1.88	.29	1.05	1.71	.26	.91
1	1.5	2.5	2.05	.47	.78	2.09	.48	.80	2.16	.49	.82	1.83	.42	.73
1	1.5	3.0	1.85	.42	.84	1.90	.43	.87	1.96	.45	.89	1.71	.39	.78
1	1.5	3.5	1.72	.39	.91	1.74	.40	.93	1.79	.41	.96	1.57	.36	.83
1	1.5	4.0	1.57	.36	.96	1.61	.37	.98	1.64	.38	1.00	1.46	.33	.88
1	1.5	4.5	1.43	.33	.98	1.46	.33	1.00	1.51	.35	1.06	1.34	.31	.91
1	2.0	3.0	1.70	.52	.77	1.73	.53	.79	1.78	.54	.81	1.54	.47	.73
1	2.0	3.5	1.57	.48	.83	1.61	.49	.85	1.66	.50	.88	1.44	.44	.77
1	2.0	4.0	1.46	.44	.89	1.48	.45	.90	1.53	.47	.93	1.34	.41	.81
1	2.0	4.5	1.36	.42	.93	1.38	.42	.95	1.43	.43	.98	1.26	.38	.86
1	2.0	5.0	1.27	.39	.97	1.29	.39	.98	1.33	.39	1.03	1.17	.36	.89
1	2.5	3.5	1.45	.55	.77	1.48	.56	.79	1.51	.58	.81	1.32	.50	70

1	2.5	4.0	1.35	.52	.82	1.38	.53	.84	1.42	.54	.87	1.24	.47	.75
1	2.5	4.5	1.27	.48	.87	1.29	.49	.88	1.33	.51	.91	1.16	.44	.80
1	2.5	5.0	1.19	.46	.91	1.21	.46	.92	1.26	.48	.96	1.10	.42	.83
1	2.5	5.5	1.13	.43	.94	1.15	.44	.96	1.18	.44	.99	1.03	.39	.86
1	2.5	6.0	1.07	.41	.97	1.07	.41	.98	1.10	.41	1.03	.98	.37	.89
1	3.0	4.0	1.26	.58	.77	1.28	.58	.78	1.32	.60	.80	1.15	.52	.72
1	3.0	4.5	1.18	.54	.81	1.20	.55	.82	1.24	.57	.85	1.09	.50	.75
1	3.0	5.0	1.11	.51	.85	1.14	.52	.87	1.17	.54	.89	1.03	.47	.78
1	3.0	5.5	1.06	.48	.89	1.07	.49	.90	1.11	.51	.93	.97	.44	.81
1	3.0	6.0	1.01	46	.92	1.02	.47	.93	1.06	.48	.97	.92	.42	.84
1	3.0	6.5	.96	.44	.95	.98	.44	.96	1.00	.45	1.01	.88	.40	.87
1	3.0	7.0	.91	.42	.97	.92	.42	.98	.94	.42	1.05	.84	.38	.89
1	3.5	5.0	1.05	.56	.80	1.07	.57	.82	1.11	.59	.85	.96	.50	.76
1	3.5	5.5	1.00	.53	.84	1.02	.54	.85	1.06	.56	.89	.92	.48	.78
1	3.5	6.0	.95	.50	.87	.97	.51	.89	1.00	.53	.92	.88	.46	.80
1	3.5	6.5	.92	.49	.91	.93	.49	.92	.96	.51	.95	.83	.44	.82
1	3.5	7.0	.87	.47	.93	.89	.47	.95	.91	.49	.98	.80	.43	.85
1	3.5	7.5	.84	.45	.96	.86	.45	.98	.86	.47	1.01	.76	.41	.87
1	3.5	8.0	.80	.42	.97	.82	.43	1.01	.81	.45	1.04	.73	.39	.89
1	4.0	6.0	.90	.55	.82	.92	.56	.84	.95	.58	.87	.83	.51	.77
1	4.0	6.5	.87	.53	.85	.88	.53	.87	.91	.55	.90	.80	.49	.79
1	4.0	7.0	.83	.51	.89	.84	.51	.90	.87	.53	.93	.77	.47	.81
1	4.0	7.5	.80	.49	.91	.81	.50	.93	.84	.51	.96	.73	.44	.83
1	4.0	8.0	.77	.47	.93	.78	.48	.95	.81	.49	.98	.71	.43	.86
1	4.0	8.5	.74	.45	.95	.76	.46	.98	.78	.47	1.01	.68	.42	.88
1	4.0	9.0	.71	.43	.97	.73	.44	1.01	.75	.45	1.04	.65	.40	.89
1	5.0	9.0	.66	.50	.90	.67	.52	.93	.70	.53	.96	.61	.46	.83
1	5.0	10.0	.62	.47	.95	.63	.48	.96	.65	.50	1.00	.57	.43	.87

also to fill the voids between the stones. The voids between the stones are smallest when the stones are not all of the same size but vary from the coarsest down to the $\frac{1}{4}$-inch size. For such stones a commonly used mixture is one part of cement, two parts of sand, and four parts of stone, commonly written 1 : 2 : 4; but richer mixtures, such as 1 : $1\frac{1}{2}$: 3, are occasionally used for very thin reinforced-concrete sections and columns, also for certain kinds of concrete pavements. Leaner mixtures, such as 1 : $2\frac{1}{2}$: 5, are frequently used in architectural work for basement walls and the like. The mixture 1 : 3 : 6 is about as lean as concrete should be mixed. This mixture may be used for heavy walls, also for cellar floors where it is intended to cover the concrete with a wearing surface of some kind, such as a wooden floor or a cement finishing coat. It is also used in making cinder concrete that is used to fill in over slabs of concrete which are used in fireproof floors.

30. Quantities of Materials Required for Concrete. Concrete is usually measured by the cubic yard, and tables giving the quantities of materials are usually based upon the cubic yard as a unit. There are 27 cubic feet in a cubic yard.

The amounts of cement, sand, and stone required to make up 1 cubic yard of concrete vary with the mixture, a richer concrete requiring more cement per cubic yard than a lean concrete. The quantities also vary according to whether the aggregates are well graded in size or not.

31. Table I.—Table I gives the quantities of ingredients that will be required to make 1 cubic yard of rammed concrete, or concrete that is tamped or rammed into its position, when the ingredients are used in different proportions. It is assumed that materials of average quality are used such as will customarily be employed in actual practice. The following example will illustrate the use of this table:

EXAMPLE.—What quantities of the various ingredients will be required to make 20 cubic yards of 1 : 2 : 4 stone concrete, using stone 1 inch and under in diameter with the dust screened out?

SOLUTION.—In Table I it will be seen that for a 1 : 2 : 4 mixture, using 1-inch stone and under with dust screened out, 1.46 bbl. of cement,

.44 cu. yd. of sand, and .89 cu. yd. of stone will be required to make 1 cu. yd. of concrete. For 20 cu. yd. of concrete the following will be required:

$$\left.\begin{array}{l}20\times 1.46=29.20 \text{ bbl., or 117 bags of cement}\\ 20\times\ .44=\ 8.80 \text{ cu. yd. or 9 cu. yd. of sand}\\ 20\times\ .89=17.80 \text{ cu. yd. or 18 cu. yd. of stone}\end{array}\right\}\text{Ans.}$$

When estimating the quantities required for a given job, an allowance of about 5 per cent. additional should be made for waste.

32. Amount of Water Required.—The amount of water required in concrete varies greatly, because the concrete may be mixed wetter or drier, and also because the materials may absorb a smaller or a greater quantity of water. The proportion of cement used also has a great influence upon the amount of water used. However, as a rough approximation, it may be stated that it takes one gallon of water to each cubic foot of the solid ingredients used in the batch.

33. Consistency of Concrete.—Concrete mixtures are usually classed as *dry, medium,* or *wet,* according to the amount of water used in them. The concrete generally used for construction work is a medium mixture, which produces a concrete of such consistency that it will flow sluggishly into the forms without separation of the materials. If less water is used, the mixture becomes so stiff that it cannot be properly placed in the forms. If more water be used, the aggregates settle in the mass and cause pockets of water to be formed which produce voids in the finished concrete or a soft chalk-like product is formed that has no strength.

If too much or too little water is used, there is a loss of density and strength as compared with concrete of the proper consistency.

MIXING OF CONCRETE

34. Methods of Mixing Concrete.—There are two methods of mixing concrete, namely, by hand and by machine. Concrete is mixed by hand where only small quantities are required and where a machine is not available. Machine-mixed concrete is greatly to be preferred because the ingredients are

more uniformly mixed, and the concrete is turned out more rapidly and usually at less cost for labor.

The quantity of concrete mixed in one operation is called a *batch*. The mixing operation comprises the measuring of the several materials required for the batch, the conveying of the materials to the place where they are to be mixed, the mixing and the delivery of the concrete to the tower, elevator, conveyors, or other means by which the concrete is taken to its destination.

HAND MIXING

35. The arrangement of the apparatus required for mixing concrete by hand is shown in Fig. 2. In (*a*) are shown the mixing board at *a*, the water supply at *b*, a quantity of cement in bags at *c*, a pile of sand at *d*, and a pile of broken stone or other coarse aggregate at *e*. Boards *f* form a runway for the wheelbarrows by means of which the sand and coarse aggregate are conveyed to the platform.

36. Assume that a two-bag batch of stone concrete is to be mixed in the proportions 1 : 2 : 4. There will be needed 2 bags of cement, 4 cubic feet of sand, and 8 cubic feet of stone for each batch.

The 2 bags of cement are counted as 2 cubic feet. To measure 4 cubic feet of sand, a box is made which is 2 feet square, 1 foot deep, and without a bottom. This box is placed on the mixing board and sand is brought in wheelbarrows and dumped into it until the box is exactly filled. The sand in the box is leveled off and the box is raised by means of the projecting sides, which are formed into handles. The sand is then spread out in an even layer, and on top of this the cement is evenly spread as indicated in (*b*).

37. Laborers stationed at the points *x* and *y* begin to mix the cement and sand by each taking a shovelful and turning it over at the spaces marked *1* and *2*. The material is shaken off the shovels instead of being merely dumped off. Each man works on his own side of the dividing line *A A*, until all the cement and sand has been turned over. The operation is then

reversed and all the material is shoveled back to the first position. The mixed cement and sand are then in a layer on one side of the board, as indicated in (*c*).

38. A stone-measuring box *a*, 2 feet wide by 4 feet long and 1 foot deep, which will hold exactly 8 cubic feet, is placed

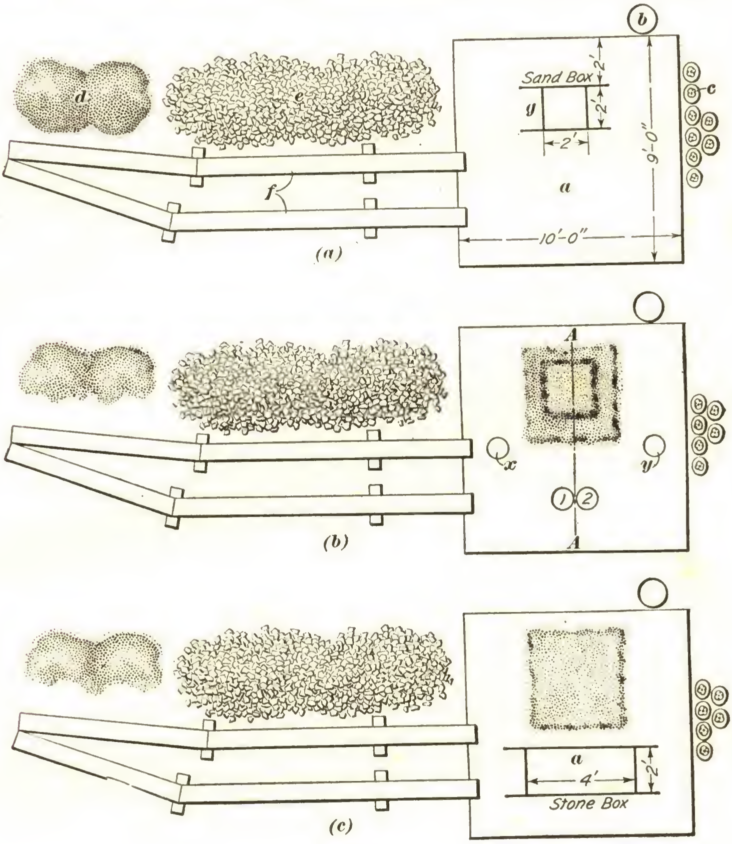


Fig. 2

alongside the sand-and-cement mixture and filled from the supply pile of stones. This box, which is also without bottom, is lifted up and removed, and the stone is shoveled over the sand-and-cement pile. The mass is then turned over as before, water being added gradually from a bucket. This turning

operation is repeated three times, after which there should be no streaks of different color in the pile, but the entire mass of concrete should be of uniform color and consistency. The concrete is then shoveled into wheelbarrows and wheeled to its destination.

39. As has been stated under the heading of Proportioning of Mortar, the measuring of the aggregates is usually done in wheelbarrows instead of boxes, although the method of using boxes is more accurate. The use of the wheelbarrow is economical in time and more convenient, but it is advisable to specify that the materials shall be mixed by the use of boxes, though the contractor may be allowed to use the wheelbarrow method as long as it is carefully done.

The contents of the wheelbarrow should be accurately ascertained so that the amount of aggregates shall be in proper proportion to the cement.

MACHINE MIXING

40. Mixing Machines.—There are two types of mechanical concrete mixers, known as *batch mixers* and *continuous mixers.* The batch mixers are designed to receive a given quantity or batch of materials, which is placed in the machine, thoroughly mixed, and discharged into buckets or wheelbarrows. The machine is then supplied with a new batch of materials and the process repeated. In the continuous mixers, as the name implies, the materials are supplied, mixed, and the concrete is discharged continuously, unless the machine is stopped. In these mixers there is always a possibility that the spouts, bins, or hoppers, from which the various materials are fed to the machine, may become clogged or stopped up, thus causing the ingredients to be fed in different proportions than were intended. This may lead to serious imperfections in the quality of the concrete.

41. Batch Mixers.—There are several kinds of batch mixers, one of the most common forms of which is illustrated in Fig. 3. At *a* is shown a receptacle, called an *automatic skip, side loader,* or *pivot hopper,* into which the amounts of cement,

sand, and stone necessary to make one batch are dumped. The skip is then elevated by means of ropes and pulleys to the position shown by the dotted lines *b*, when the materials will slide out into the drum *c*. A measured amount of water is introduced from the tank *e*. The drum revolves and lifts the cement, sand, and stone up inside the drum by means of blades that are riveted to the inside. When the material reaches the

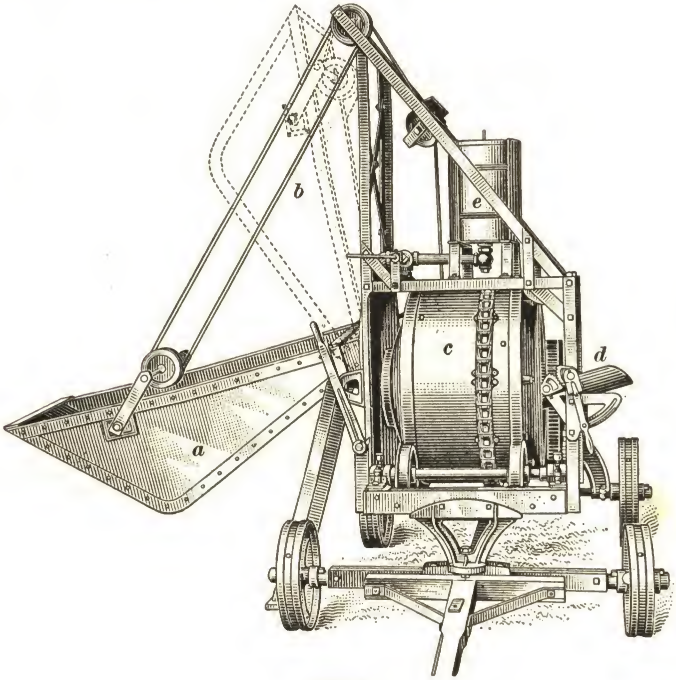


FIG. 3

top of the drum it is dropped to the bottom and picked up by other blades. This process is rapidly repeated and the materials become thoroughly mixed.

To discharge the mixed concrete, a small chute *d* is swung into the opening on the side of the drum opposite to that from which the materials enter and the concrete falling upon the upper end of this chute slides out into wheelbarrows, conveyors, or buckets.

42. While the mixing is going on in the drum, the skip is lowered and measured quantities of materials to form another batch are placed in it. When the mixed concrete has been discharged, the skip is raised and the new batch is dumped into the drum and is mixed and discharged. It will thus be seen that this process is practically a continuous one, but that concrete of the proper proportions can always be obtained.

43. Batch mixers may be driven by steam, gasoline, or electric power. For very large work, mixers operating by the action of compressed air have been used, but the installation of such huge machines is too expensive for the class of work with

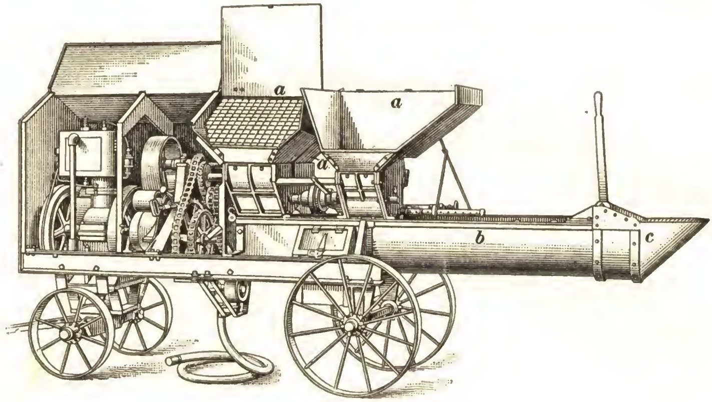


FIG. 4

which the architect is identified, being used mostly for purely engineering works such as tunnels and foundations requiring large quantities of concrete.

44. Continuous Mixers.—Continuous mixers usually consist of a feeding device and a trough in which is a screw that mixes and pushes the concrete from one end of the trough to the other. One form of such mixer is shown in Fig. 4. At *a* are hoppers that constitute the feeding device. These hoppers contain the cement, sand, and stone and are provided with slides which are used to gauge the amount of materials that are fed into the mixing trough.

The screw in the mixing trough *b* is not a solid screw which would merely push the materials forward, but is divided with blades which also mix the concrete while pushing it to the point *c*, where it is discharged. In this form of mixer the materials are shoveled into the hoppers, and special care must be taken that the hoppers do not become empty while the machine is in operation or the mixture will be deficient in some of the necessary ingredients.

45. Water Supply.—One important feature of all concrete mixers is the device for supplying water. In continuous mixers the water is usually fed to the concrete through a pipe over the mixing trough and extending parallel with it. This pipe is perforated with holes which allow the water to escape gradually so as to feed the water to the mixture along a portion of the length of the mixing trough.

In batch mixers, a tank *e*, Fig. 3, is usually mounted over the drum. This tank has an outlet into the mixer drum and every time the mixer is loaded a constant quantity of water is drawn from the tank into the mixer. The tank can be adjusted to give any desired quantity and so long as the setting of the adjustment is left undisturbed the tank will deliver the same constant amount of water to each batch, thus making for uniformity in the consistency of the concrete.

46. Mixing in Cold Weather.—If concrete is mixed in very cold weather, every precaution should be taken not to incorporate frozen materials in the mixture. This may be guarded against by heating the sand, stone, and water before they are placed in the mixer. The sand and stone are often heated by means of steam pipes which run through the piles, although any other method may be used which will be equally effective.

Concrete which is mixed and deposited during cold weather requires also to be protected against freezing. The manner in which this is accomplished will be described later.

CONVEYING OF CONCRETE

47. Methods Used.—Concrete may be delivered at the forms by any of several methods. It may be discharged from the mixer into wheelbarrows or carts and wheeled directly to the forms. It may be discharged from the mixing machine into wheelbarrows or carts which are raised by means of an elevator to the height required by the construction and wheeled from the elevator to the forms. It may be discharged from the mixer into buckets which are raised by an elevator to a desired height where the buckets are tilted automatically and the concrete discharged into a bin. From this bin it may be discharged into wheelbarrows or carts and wheeled to the forms or it may be discharged from the bin into spouts or chutes that are inclined sufficiently to cause the concrete to flow under its own weight down the chutes to the forms that are to be filled.

48. The method of wheeling directly to the forms is most commonly used on small structures or for those which are located below the level of the mixing equipment, as the wheeling of concrete can be undertaken only on a down grade or on the level. Elevating the loaded wheelbarrows or carts is employed when temporary lifts for hoisting materials have been installed in the building and can be used in hoisting wheelbarrows of concrete rapidly from the ground floor to the level at which it is to be poured.

49. When large quantities of concrete are required or the structure is of a large area, however, the elevator and a spouting system will be found to be a cheaper method of handling the concrete, since there is very little labor required and this saving in the cost of labor will offset the cost of the special equipment.

In the great majority of cases it becomes necessary to elevate the concrete before it is conveyed, and a concreting plant thus includes an elevating and distributing system as will be described later.

50. Wheelbarrows, Carts, and Cars.—Concrete is frequently wheeled by means of the familiar wheelbarrow propelled by a laborer. This method is, however, not economical, because only 2 or 3 cubic feet of concrete can be wheeled in a wheelbarrow without spilling. The concrete cart, Fig. 5, holds from 5 to 6 cubic feet, and since the load is balanced over the large wheels, the laborers have to exert themselves no more to convey the large amount in the cart than the small quantity in the wheelbarrow, if the runways are level; if the concrete has to be raised ever so little, the cart is too heavy for one man. If it is desired to wheel still larger quantities, the hopper car shown in Fig. 6 is used. This car is made in many sizes to hold from 15 to 54 cubic feet of concrete. It is always propelled by machinery, and runs on tracks. On the bottom is a gate *a*, with a handle *b* for its operation. The concrete issues from this gate in a wide stream but this stream is easily regulated, thus making it possible to fill thin walls directly from the car.

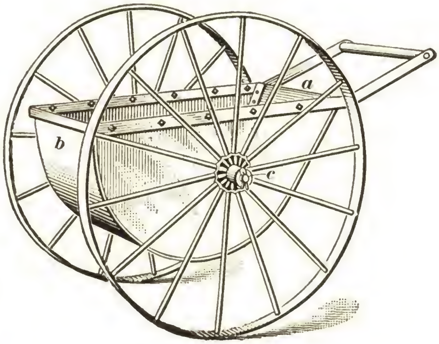


Fig. 5

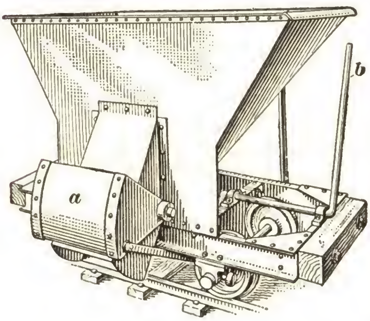


Fig. 6

51. Concrete Elevators of Wood.—A concrete elevator or tower, in which the concrete is raised in a bucket, is illustrated in Figs. 7 and 8. Such a tower is generally constructed of wood and consists of corner posts which are securely framed together and braced as shown at *a*. At *b* is a bucket which is hoisted up and down

is removed the posts are cut off just above the concrete and the concrete base is left in the ground and covered up.

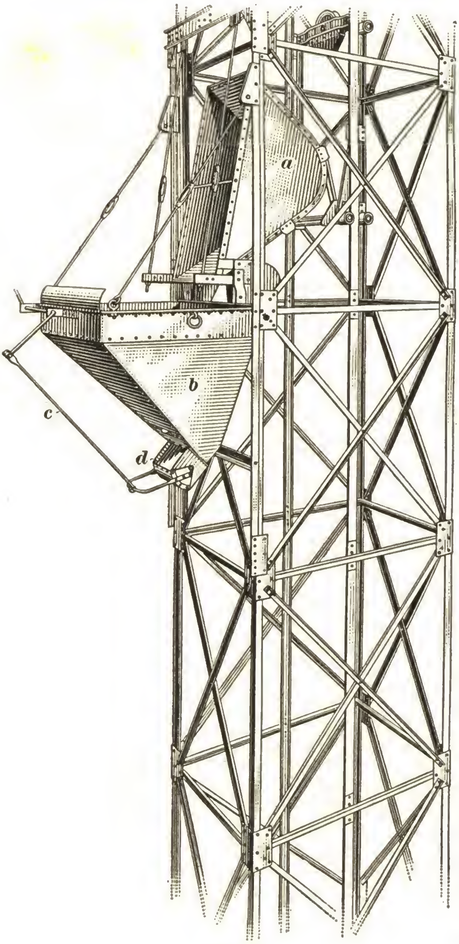


Fig. 9

To the right in Fig. 7 is a plan showing the relative positions of the tower, the mixer, and the motor which operates both.

52. Concrete Elevators of Steel. For tall buildings, elevators or towers formed of light rolled-steel shapes are often used. These are made in units of a given height which are connected to each other by means of bolts. After the building is completed the tower can be taken apart and the units stored for future use.

The initial cost of a steel tower exceeds that of a wooden one, but it has the advantage of being available for repeated use with very little expense, if properly taken down and cleaned after each structure has been completed.

53. In Fig. 9 is shown a portion of a steel-frame tower. At *a* is shown the bucket in a tilted position as it appears when the concrete is being discharged into the hopper *b*. In this

illustration at *c* is shown the device that controls the discharge of the concrete from the hopper *b*, through the outlet *d*.

The mixers are sometimes placed immediately adjoining the tower on a platform that is elevated sufficiently above the grade

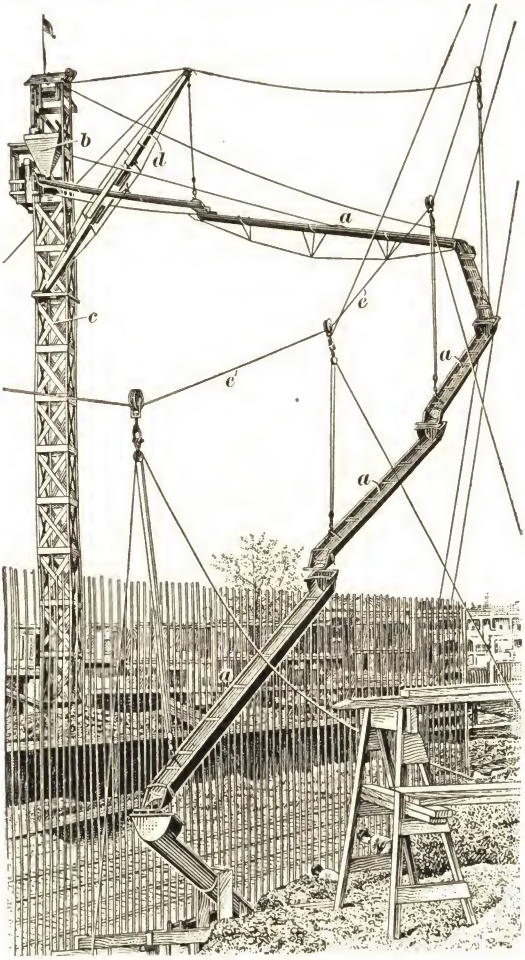


Fig. 10

level to allow the concrete from the mixer to fall into the bucket, which rests on the soil. In this method of handling the concrete, inclined runways are required between the sup-

quently followed is to cast the columns first and then cast the floor construction in sections. In this method the concrete is placed in the column forms to the height of the under side of the beam forms, the remaining part of the column and the beams being cast with the floor. In casting the floor, joints in the slabs are usually made midway between the beams where the one pouring is to cease; in the beams, midway between the girders; and in the girders, midway between the columns. These joints are formed by placing stop boards temporarily in the positions desired to prevent the concrete from flowing beyond these places. When ready to pour the next section, these boards are removed. In this method it is necessary to start each new section before the concrete of the preceding section has become hard, otherwise there will be no bond between the sections.

59. Handling.—The concrete mixture which is placed in the forms needs but little handling in order to fill the form, but what little handling is needed is indispensable in order to drive out the air which would otherwise be trapped in the concrete and produce voids. The purpose in all concrete work is to have the concrete as dense and compact as possible, and this is obtained only by eliminating the voids.

The air pockets often form rather large voids. There is, however, another kind of voids, which are very small and appear mostly at the surface of the concrete where it is in contact with the forms; these voids are caused by a local surplus of water which assembles in small globules and, upon evaporation, leaves empty spaces. Other very unsightly voids in the face of the work are those known as stone pockets; these occur where the mixture was imperfect to begin with or became imperfect through separation of the coarser aggregates from the mortar.

60. Slicing.—For the reasons mentioned, the manipulation of the concrete in the forms is a necessity. The most commonly used tool for this purpose is the *slice bar,* or spade, shown in Fig. 11, which is used as shown in Fig. 12. By inserting the blade between the forms and the concrete and pressing

the coarse particles back into the body of the concrete, a dense skin of mortar is obtained at the surface. By working the

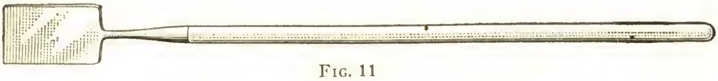


Fig. 11

blade up and down in the mass of plastic concrete in the forms, the air is driven out. By these two methods the concrete is made to lodge in the forms in a dense and well-packed mass.

In some cases it may be impossible, owing to the complicated forms, or other obstructions, to slice and work the concrete properly. In such cases, it is necessary to pound the outside of the forms with heavy wooden mallets, which has the effect of shaking the concrete down and giving the air an opportunity to escape.

61. Wetting.—Since water is such a necessary part of the concrete and since without it the cement cannot harden, it becomes very necessary to guard the concrete against drying too rapidly, especially in summer. Concrete contained within forms is not affected under ordinary conditions, but the surfaces of floors and pavements present such a large area to the rays of the sun that the concrete is affected unfavorably. The remedy is to cover the concrete with boards, straw, or moist earth and to keep the concrete and its covering wet by sprinkling for several days after it is laid.

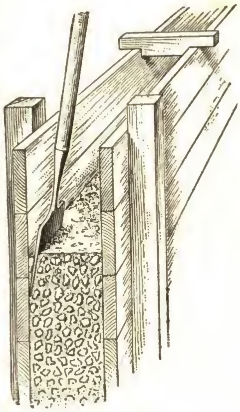


Fig. 12

62. In Freezing Weather.—Concrete that is deposited in cold weather requires to be protected against freezing. A floor or sidewalk construction is usually covered with a heavy tarred paper on which is placed a quantity of hay or straw, and boards laid on this to hold it in place. Canvas is sometimes used to form a covering over a floor and is supported on a framework of wood. This framework is made sufficiently high

so that salamanders may be placed beneath the canvas and fires be kept burning so as to maintain a temperature that will be above the freezing point. In addition to this protection for the floor construction, the sides and ends of a building are often enclosed with large sheets of canvas, and salamanders are placed in the story below the newly formed concrete floor. This method of heating produces a warmth under the floor construction and facilitates the setting of the cement in the concrete floor, beams, girders, and columns.

While concrete which has been frozen will usually harden in a satisfactory manner after thawing out, repeated freezing and thawing will injure it.

Another danger is that frozen concrete may be mistaken for hardened and seasoned concrete and the forms removed before the concrete is sufficiently strong to be self-supporting. To determine whether concrete is frozen or hardened, pour a quantity of hot water upon the concrete and if the concrete remains hard, it has set, but if it softens, it is frozen.

PLAIN, OR MASS, CONCRETE

63. Definition.—By **plain,** or **mass,** concrete is meant concrete in which reinforcing steel is not employed. It is used in the more bulky or massive parts of a structure such as the footings and foundation walls of buildings, and in retaining walls. Mass concrete is poured into prepared forms or molds and is allowed to harden, after which the forms are removed. Mass concrete is also used in making sidewalks, pavements, and floors.

APPLICATION OF PLAIN CONCRETE

64. Footings.—The footings used in building work may be considered under two divisions, namely, *column* or *pier footings,* and *wall footings.*

65. Column Footings.—Column or pier footings are placed under columns or piers and support a single concentrated load.

The simplest type of column footing, shown in Fig. 13, consists of a single layer of concrete *a*. Upon this layer a pier *b* may rest directly as shown. The thickness *d* of the footing is determined by the amount of projection *c*, and should be one and three-quarters to twice the distance *c*. If the projection is made greater than these amounts it may break off when the load is applied on the pier.

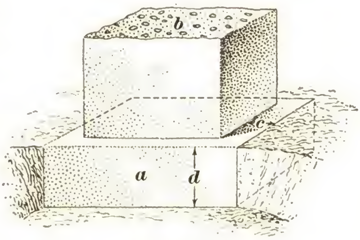


FIG. 13

66. Stepped Footings. Where a greater projection of the footing is required, which will be the case when the load is to be greater or where the supporting soil is soft, the thickness of the footing must be

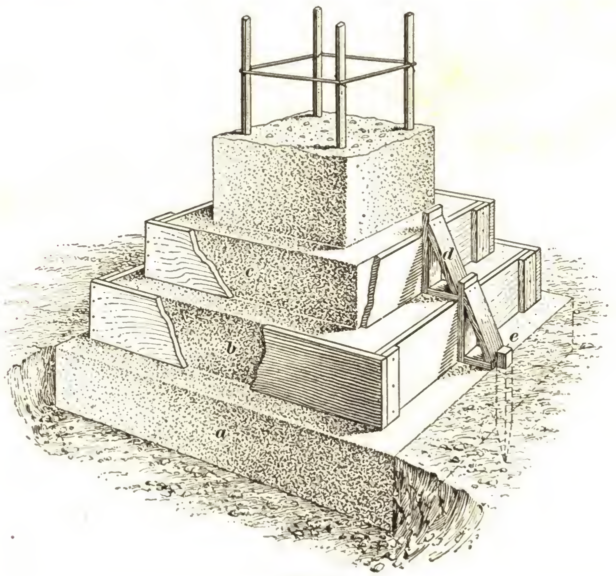


FIG. 14

increased. Instead of building the footing in a single cube-like mass, it may be made, as illustrated in Fig. 14, in steps, thereby saving considerable concrete. The concrete omitted

from above the steps does not detract from the strength of the footing. The footing shown in Fig. 14 is formed of three steps, each of which is cast separately. The lowest step *a* is cast in a mold or form made by digging a rectangular hole in the ground and filling it with concrete. The second step *b* is next cast in a wooden form, as is also the step *c*.

The forms for these steps are shown broken away, to illustrate their shape and the method of using them.

67. Tapered Footings.—In Fig. 15 is shown a tapered footing *a*, which for the same size of top and bottom surfaces and the same height is just as strong as the type shown in Fig. 14.

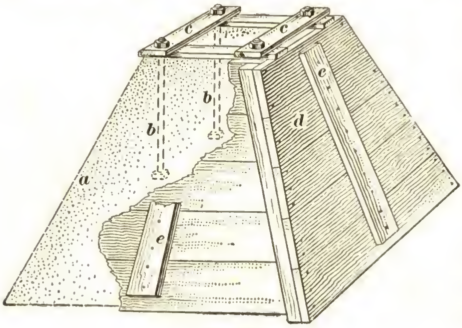


FIG. 15

68. Footings for Steel Columns. Where steel columns are to stand upon concrete footings it is necessary that they be securely bolted or anchored to the footing. This is done, as shown in Fig. 15, by means of steel bolts *b* which are embedded in the concrete and project above the top surface of the footing and through the bottom plate of the column, thus making a strong connection. The bolts must be accurately set in the concrete in such positions that when the column is set on the footing they will enter the holes in the column and can be secured by nuts. The bolts are located accurately and kept in place while the concrete is being poured, by use of a wooden templet, or pattern, *c*, in which holes are bored at proper points to receive and hold the bolts, and this templet is securely fastened to the top of the form *d* in which the footing is cast. The position of the footing and templet must be very carefully located, and they must be set true as regards the lines and levels which regulate the positions and the levels of the under sides of the column bases.

69. Wall Footings.—A concrete wall footing is a layer of concrete which is placed on the soil for the wall to rest upon. The thickness of the footing depends upon the distance that it projects beyond the face of the wall, and is determined by the same rule as that given for column footings. Concrete footings are often used for walls that are constructed of other materials, such as stone or brick, as well as for concrete walls.

An example of the use of a concrete footing for a concrete foundation wall of a dwelling house is shown at *a* in Fig. 16.

70. Plain - Concrete Walls. — Plain - concrete foundation walls of buildings are usually buried underground for their greater part, and the portion below ground needs no special ornamental surface treatment. The portion of the foundation wall above ground, also the walls of the superstructure, when formed of concrete is generally given an ornamental surface treatment.

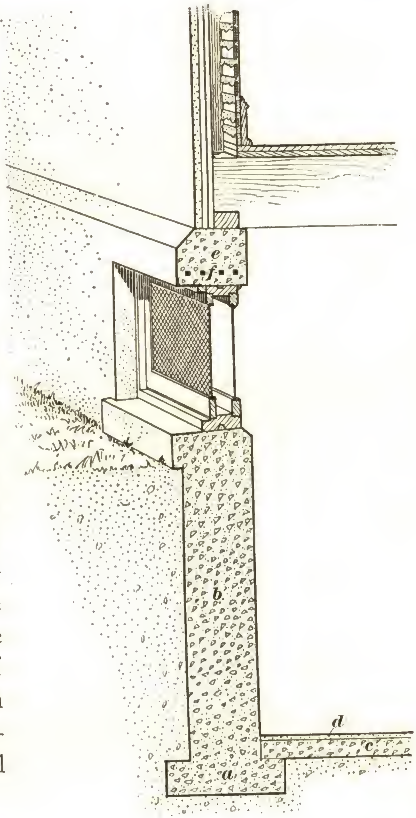


Fig. 16

71. In Fig. 16 is shown a section through a plain-concrete cellar wall. This wall stands on a simple footing course *a*, and the part of the wall below the surface of the ground is shown at *b*. The part of the wall above the ground contains the windows that give light to the cellar, and above the window shown is formed a concrete lintel that is reinforced by means of the steel bars shown in section

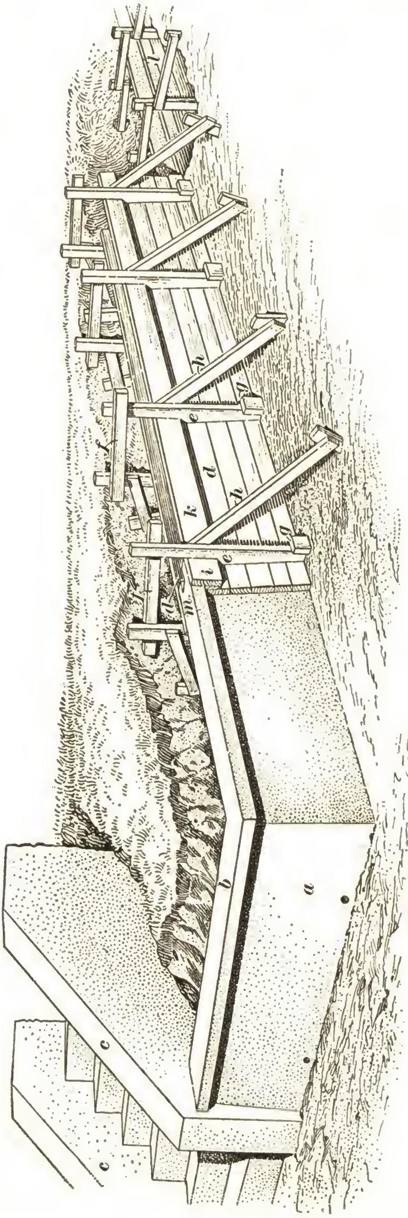


Fig. 17

at *f*. A cellar floor of concrete is shown at *c* and the finished wearing surface of the floor at *d*.

72. Retaining Walls. — Another use for plain or mass concrete is in building *retaining walls*. An example of a retaining wall which serves to hold up a small terrace is given in Fig. 17. At *a* is shown the finished wall; at *b*, a coping which projects beyond the face of the wall to shed rain, as well as to form a finish for the wall. A similar wall without coping is shown at *c* on each side of the steps.

73. A cross-section of this retaining wall is indicated in Fig. 18, the part above ground and the outline of the terrace back of the wall being shown dotted. Behind the wall, just below the coping *d*, is shown a gutter *e*, which serves to catch

the water that flows down the terrace and lead it away so that it will not seep down back of the wall. Any water that does

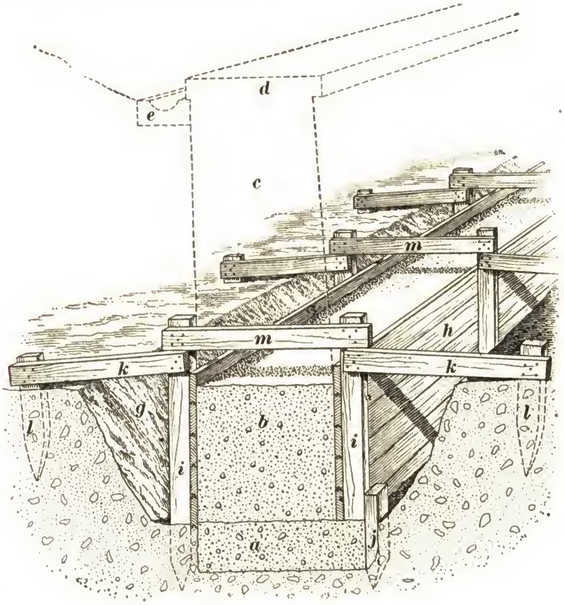


FIG. 18

penetrate the earth behind the wall can escape through the pipe-like holes formed in the wall just above the grade, as shown in the wall *a* in Fig. 17.

After the wall has been completed the soil is filled in back of the wall as indicated by the dotted outline in Fig. 18. The part filled in is sometimes called the *back fill.*

FORMS FOR PLAIN CONCRETE

74. Forms for Footings. — A form is not usually required for the construction of a footing such as is shown in Fig. 13, as a space the exact size of the footing can generally be excavated in the soil and filled with concrete. When, however, as in gravel or sand, the sides of the excavation will not remain vertical, wooden forms are used. A form for a footing such as shown in Fig. 13 may be made of four boards cut to

the required lengths and nailed together in the form of a box. Stakes, driven in the ground outside such a form, hold it in place and prevent the sides from bulging when the concrete is poured into it.

75. The form for a footing such as shown in Fig. 14 is made in sections. If possible, the form for the lowest part of the footing *a* is made in the soil without the use of wood. If the sides of the excavation will not stand up, board forms must be used for this section. In either case forms must be provided for the sections *b* and *c* somewhat as shown in the figure. These forms are held in position by braces *d*, which are fastened to the stakes *e* and to the forms.

76. A part of a form for a tapered footing is shown at *d* in Fig. 15. This form is made of planks having their ends cut to a bevel as required by the shape of the footing. The planks of each side are held together by means of battens *e* and the sides of the frame are also nailed together at the corners. Interior cross-braces are sometimes used to preserve the shape of the form until it is set in place, after which they are loosened and removed through the open top of the form before the concrete is poured.

77. Forms for Piers. — Fig. 19 illustrates several methods of making forms for piers. The four sides are built of planks running vertically. These sides are held together by the different devices shown. In all these, iron or steel bolts are employed, and wooden wedges are freely used to bring the various parts tightly together. In the lower right-hand illustration is shown the use of angle irons fitted to the corners of the form and drawn together by means of bolts.

The main object of these pier forms is that they shall confine the mass of concrete so that it will not move or spread out the sides of the forms, and that the finer parts of the concrete will not leak out. They are also made so that they can easily be taken down and used as forms for other columns. Further reference to forms for piers and columns will be made later. Other designs for forms will also be shown under the heading Reinforced Concrete.

78. Forms for Walls.—The forms used in the construction of a low retaining wall of plain, or mass, concrete are

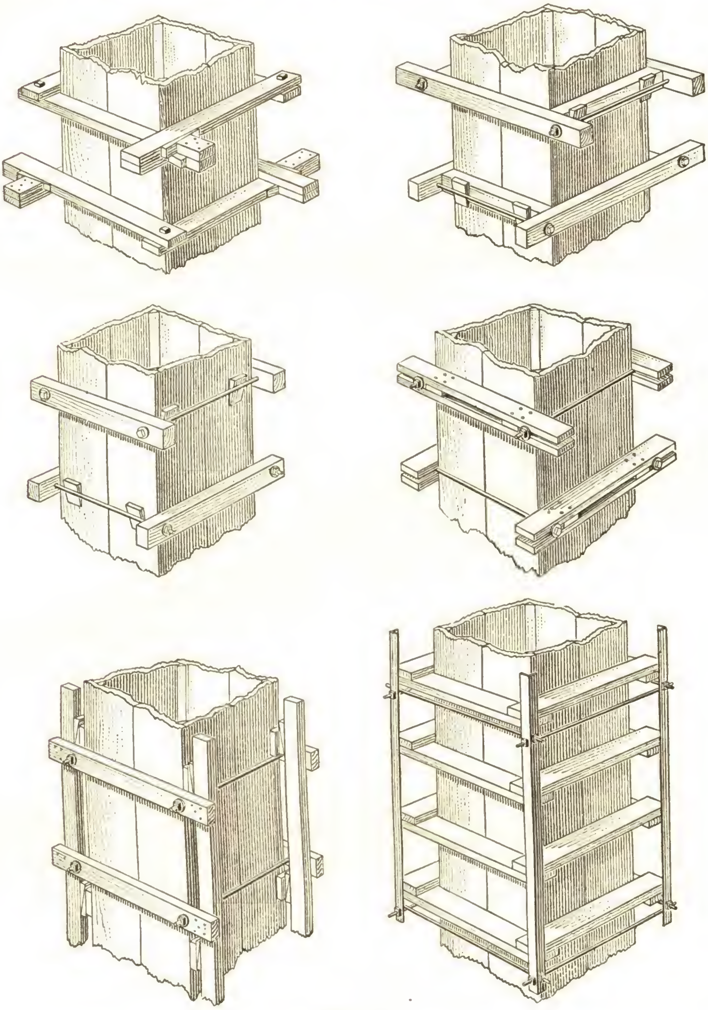


FIG. 19

shown in Fig. 17. The wall is indicated in cross-section in Fig. 18, in which *a* is the footing, *b* the wall below ground, *c* the wall above ground, and *d* the coping member.

The footing *a* is poured first, the earth being excavated to act as a form. Large-sized stones are sometimes placed in the footing and extend above its surface so as to tie the footing to the section *b*.

The excavation for the wall, as a whole, should be made of sufficient size to permit workmen to set the forms required for the portions of the wall above the footings.

The section *b* is cast in forms that are constructed as shown. The boards *h* are nailed to the uprights *i* and these are then set in place. They are held in the proper position by stakes *j* driven into the ground and by braces *k* that are nailed to them and to the stakes *l* driven at convenient points in the adjacent bank.

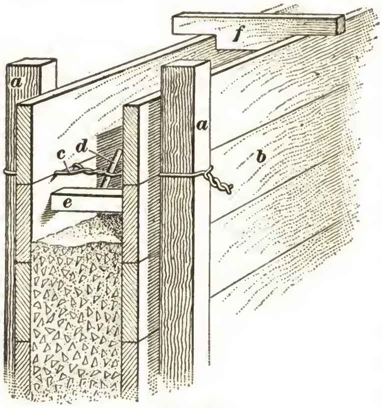


FIG. 20

Spacers *m* nailed to the uprights *i* keep the two faces of the form at the correct distance apart.

79. When the lower section of the whole wall has been finished and has had time to set, the form work is removed and the earth is shoveled and tamped into place against the wall and the forms are set for the top section of the wall as shown in Fig. 17.

80. The form used for this section of the wall consists of planks *d*, fastened to posts, or battens, *e*. The battens are held in place at the top by the spacers *f* and at the bottom by the stakes *g*, which are driven into the ground. They are further braced by the inclined braces *h*. The form is constructed to allow for the coping as shown at *i*, the battens being cut in the shape shown and the board *k* nailed outside of the lower boards *d*, thus providing for this projection.

81. Another type of wall form, for comparatively thin walls of considerable height, is shown in Fig. 20. The battens *a*, which support the planks *b*, are held together by means

of wires *c* that pass between the planks and are twisted by means of sticks *d* and tend to pull the forms together. To prevent their being pulled together too closely, spreaders *e* are placed close to the wires. These spreaders are removed as the concrete reaches their levels, as they are no longer needed, the concrete being sufficient to keep the forms apart. Spacers *f* are also used at the tops of the forms to keep the forms the proper distance apart.

After completion of the concrete work, the wire ties are cut and the forms removed, and the projecting ends of the wire ties are then dressed back as closely to the face of the wall as

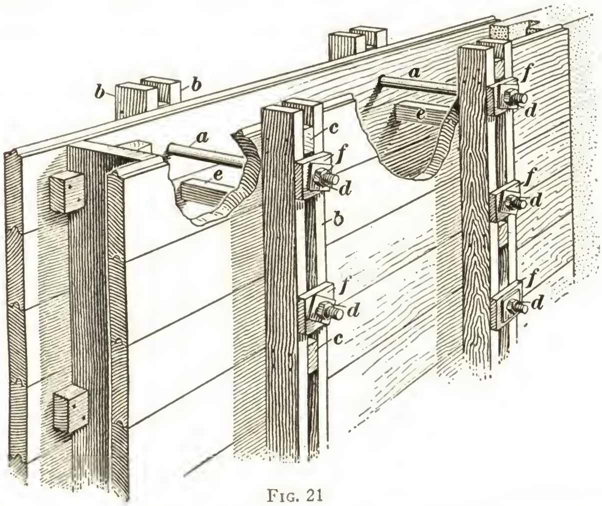


Fig. 21

possible. They will, however, rust in time and stain the walls, therefore methods that permit of the iron ties being removed entirely are preferable for work that will be seen.

82. A method by which the forms are held together by bolts instead of by wire ties is illustrated in Fig. 21. Here bolts *a* extend through battens, or posts, formed of two pieces *b* kept about 1 inch apart by means of blocks *c* nailed between them. On the ends of the bolts are applied iron washers and nuts *d* by which the battens are firmly held. The bolts are made of sufficient length to serve for the thickest walls that

are to occur in the building, and when they are used for thinner walls the difference in thickness is taken up by means of blocks of wood *f*. Wooden *spreaders e* are used to keep the sides of the form apart and are removed when the concrete reaches their levels. As soon as the wall has set and the forms have been removed, the bolts are withdrawn. There will then be no iron left in the wall to cause rust stains.

83. Steel Forms.—There are on the market many patented types of metal forms for concrete wall construction. One class consists of small units and provides for the casting of only a small amount of concrete at one time. Forms of this class are generally used for the construction of the walls of houses and other small structures. The concrete is mixed quite dry, the forms are filled by hand and the concrete thoroughly tamped to secure a compact mass. Immediately after this is accomplished, the form is removed, placed elsewhere, and another section of wall is cast.

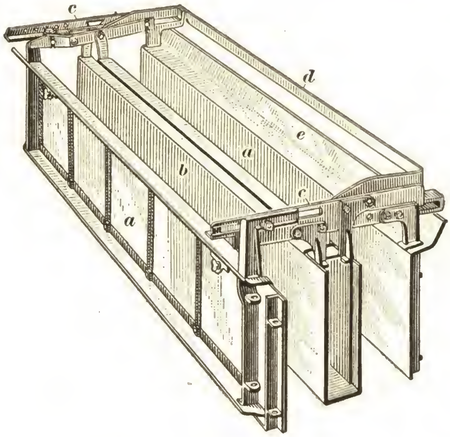


Fig. 22

Another class of steel forms, which may consist of small or of large units, provides for casting a large quantity of concrete at one time and is used where large masses of concrete are to be placed. The concrete is poured into the forms, which are left in place until the concrete has hardened, after which they can be removed and used for building other parts of the wall.

84. In Fig. 22 is shown an example of a metal form for casting a hollow concrete wall. It consists of the outside plates *a*, and the partition *b*, which forms the space between the

outer and inner parts of the wall. The cross-bars *c* are adjustable and allow of making the outer and the inner shells of the wall of different thicknesses. The flanges *e* are spread so as to prevent pouring the concrete over the outside of the form. At *d* is shown a handle which can be raised to a vertical position and is used to lift the entire form so as to remove it from the wall.

85. In Fig. 23 is shown a portion of a concrete wall in the process of construction by use of the form just described. At *a* is the outer shell of the wall, at *b* is the steel form in position

Fig. 23

and being filled with concrete. Recesses *c* are shown in the wall to receive the floor joists. These recesses are formed as shown at *d* by inserting temporary wooden blocks in the proper positions when filling the steel form. At *e* is shown one of these temporary blocks partly removed. Wooden strips *f* to be used as nailing pieces to which woodwork can be secured can be placed in the mold at any desired point.

86. Fig. 24 shows a portion of a completed wall *a*. The form *b* has just been raised and is about to be placed on the

wall to form a new section. It will be placed so as to cover the sloping end of the part just completed. A course the depth of

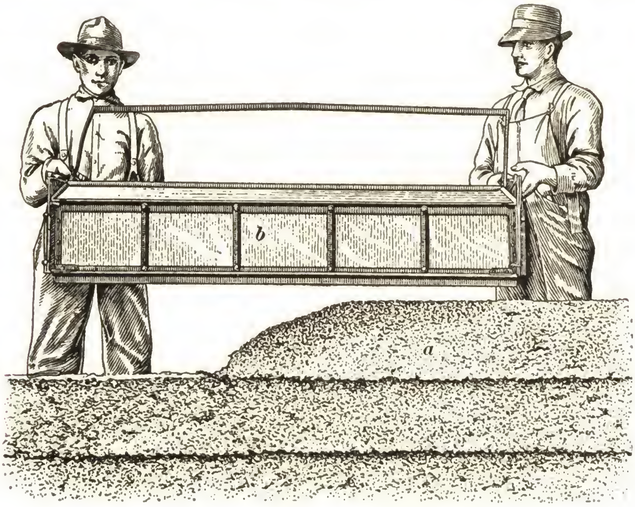


FIG. 24

the machine is cast around the building. By the time this is done the portion of the course that was cast first will be hard

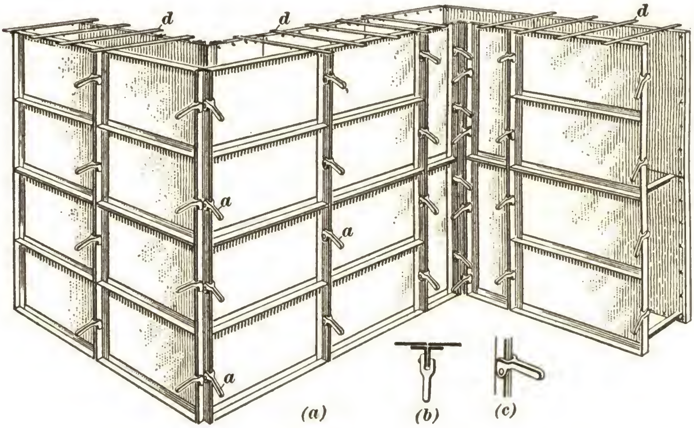


FIG. 25

enough to receive a new course on top of it. This course is carried around the building in the same manner.

87. Fig. 25 shows a form consisting of units made of galvanized sheet iron with angle-iron frames, which are assembled, locked together, tied, and braced in such a manner that they are rigid and sufficiently strong to resist the pressure of concrete in large masses. They are fastened together by the clamps *a*, which when raised up as shown cover the angles of the two adjacent units and hold them together. The clamp

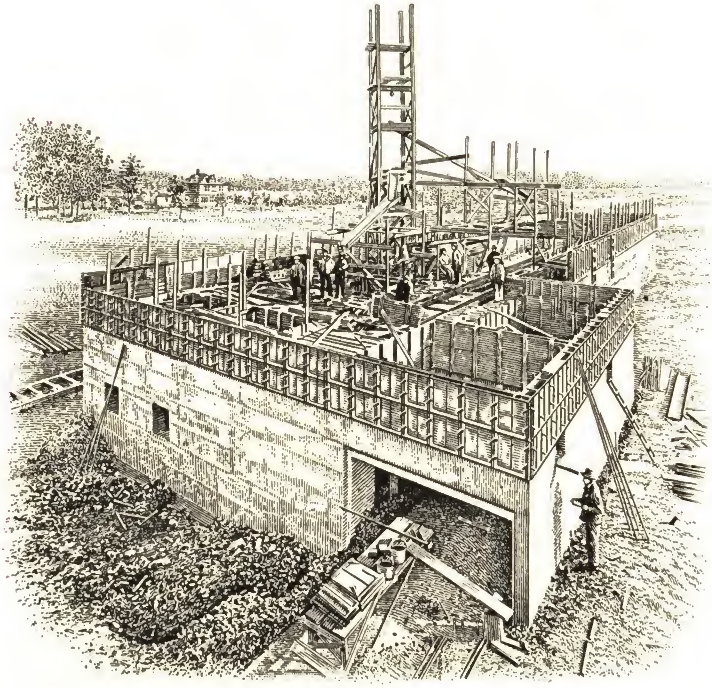


Fig. 26

is shown separately at *b*, where the observer is looking down upon it, and at *c*, which is a perspective view. The rods *d* are called *stay-rods* and are adjustable to hold the plates at the proper distance apart. The smooth surface of the galvanized iron gives a smooth finish to the surface of the wall. In Fig. 26 is shown a building in process of construction in which this type of sheet-metal form is being used

88. Forms constructed of pressed-steel uprights *a* are shown in Fig. 27. The forms between these uprights are made of sheets of steel stiffened by the wooden planks *b*, which are secured to the backs of the steel plates. These forms are light in weight, are easily handled, and are especially adapted to the

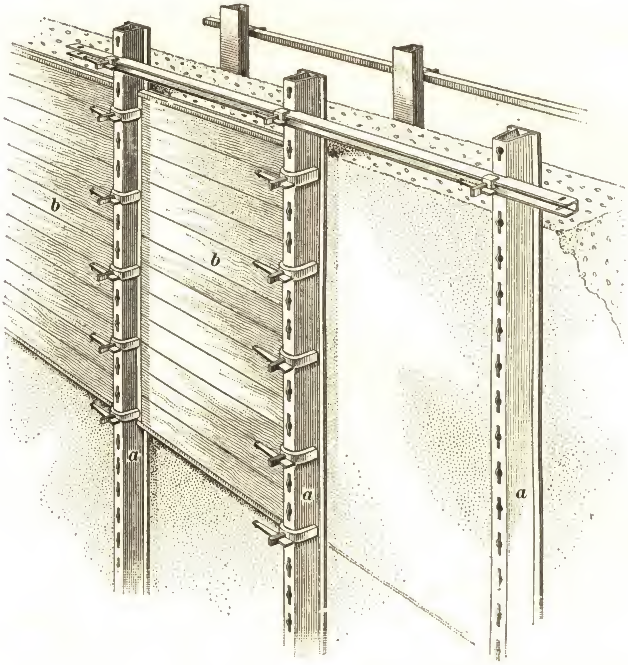


FIG. 27

construction of structures that require large masses of concrete, such as retaining walls, of which Fig. 28 is an illustration.

89. Forms for Steps.—Steps are built in forms such as are shown in Fig. 29, in which *a* indicates the concrete treads and platform, and *b* the boards that form the risers. The side forms, shown at *c*, consist of boards nailed to battens. These battens are held in place by the blocks and braces *d*. Special bracing is provided at *e* to prevent the riser boards from bulging when the concrete is placed in the form.

90. Expansion Joints.—Long retaining or other walls are provided with what are called *expansion joints* at intervals

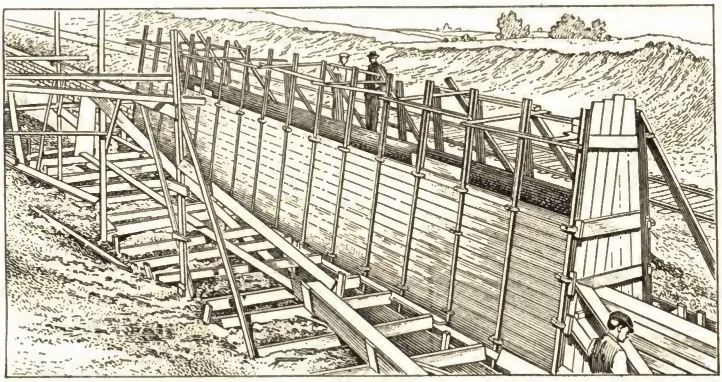


Fig. 28

of from 35 to 50 feet. These joints allow the wall to expand and contract with the change in temperature. An expansion

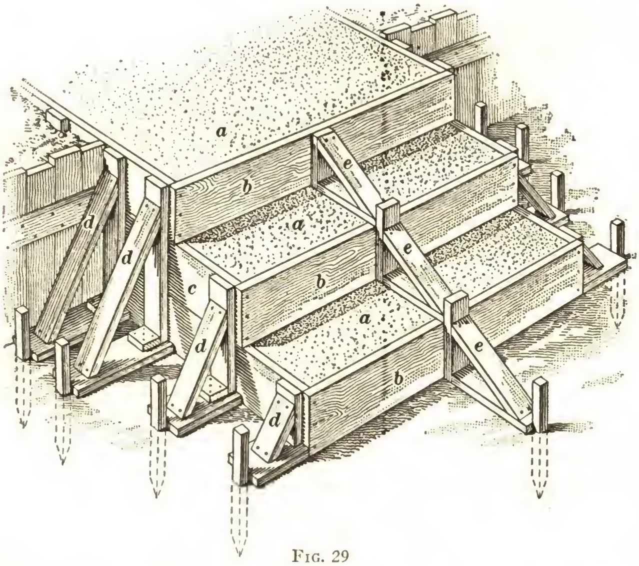


Fig. 29

joint is shown in the wall in Fig. 17 at *m* and in detail at *a* in Fig. 30. A form for such a joint is shown in Fig. 21.

In order to prevent the face of one section being pushed beyond the face of the adjacent section, the joint is formed with a tongue-and-groove construction. The end of the finished section is greased or covered with a layer of tar paper before the next section is cast against it.

91. Assembling and Removal of Forms.—Wooden forms for small structures are assembled as already described. Wooden forms for large structures are described later under Reinforced Concrete, as is also the removal of the forms and the care that should be taken of them to permit of their repeated use.

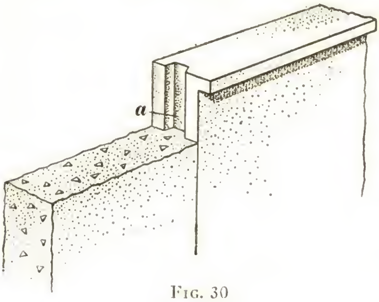


FIG. 30

The manner of assembling and removing forms of the patented types depends entirely upon the character of the forms, and the manufacturers provide detailed instructions relative to the use and care of their products. Forms of this character are usually designed so that the units are interchangeable, and also adjustable, hence the forms may be used in the construction of walls of various thicknesses and heights.

SURFACE FINISHES FOR WALLS

92. Concrete, when placed, fills every irregularity of the forms, and when the forms are removed the imprints of any defects are plainly visible on the concrete. Therefore, if it is desired to have a concrete of uniform surface, the first requisite is a form without defects or blemishes of any kind. Such a form cannot be made of wood; only steel forms are sufficiently smooth to leave no marks on the concrete.

Even when steel forms have been used, there are defects in the wall surfaces where the units, which compose the forms, adjoin each other. Furthermore, concrete is not always acceptable for high-class work because the concrete itself has a dull

grayish color which is very monotonous, and when wet it becomes streaked and blotched.

93. Methods of Finishing. — There are various methods of obtaining uniform and pleasing surfaces on concrete walls. One of these consists of washing or brushing the surface before the concrete has thoroughly hardened. Another is to tool or sand-blast the surface after it has become thoroughly hardened. A third method is to apply a facing of special concrete to the form by means of a trowel and back it up with ordinary concrete. This facing can be made of white cement mixed with marble dust, special colored aggregates, etc. These methods produce agreeable and artistic results.

94. A facing material of mortar containing one part cement and two parts of fine aggregate, such as marble screenings or colored sand, is often used. Mortars for facing should never be made richer than 1 part cement and 2 parts sand or screenings. If gravel or fine stone is to be added to the cement and sand, for a facing, the mixture may be made in the proportions of 1 : $1\frac{1}{2}$: 3 or 1 : 2 : 3. If coarse aggregate is used, the minimum thickness of the facing should be not less than twice the maximum dimension of the largest pieces of stone.

95. Surface Finishes.—Surfaces of plain concrete walls may be **brushed.** In this treatment the forms must be removed within 12 hours after the concrete is poured; then, while the surface is still comparatively soft, it is brushed with a bristle brush to remove the mortar from the surface and leave the coarse aggregate exposed. An acid wash may be applied after the brushing in order to remove the film of cement that may adhere to the stone. Such a wash should be a very weak solution of muriatic acid, and after it has been used, the acid should be carefully washed off the wall by a liberal use of clean water.

96. Rubbed Surface.—If a rubbed surface is desired, the forms are removed from the wall after the concrete is a day or two old and the surface is rubbed with a brick formed

of carborundum or emery, or with a piece of soft sandstone. A good rubbed surface is secured when the facing mixture contains little or no coarse aggregate. A thin grout composed of cement and sand should be applied during the process of rubbing and the surface afterwards washed down with clean water.

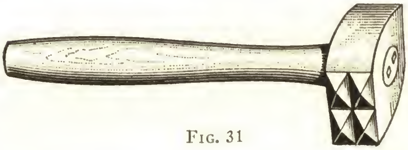


FIG. 31

97. Sand - Blasted Surface.—A sand-blasted surface has very much the same texture and finish as that obtained by brushing. This treatment is applied, however, after the concrete has become hard. Any pronounced ridges or irregularities in the surface should be removed by tooling, and cracks or open joints should be pointed some time before the surface is sand-blasted, in order that the filling may be hard.

98. Tooled Surface.—Concrete surfaces may be finished by tooling by any of the methods and in any of the styles employed for finishing natural stone. Where a surface is to be tooled, the best results are obtained when a facing material with comparatively small-sized aggregates is used, as it is hard to dress and to obtain uniform results on surfaces when large stones are encountered. Concrete should be thoroughly hard

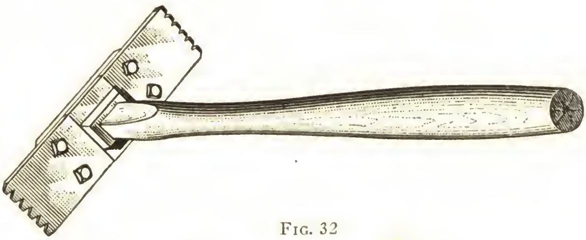


FIG. 32

before being tooled, especially if sharp edges and surfaces of a fine uniform texture are desired.

99. Tools.—Tools that are frequently used for surfacing concrete walls are the *bush hammer*, shown in Fig. 31, and the *concrete ax*, shown in Fig. 32. Where compressed air is avail-

able, the concrete may be dressed with a *pneumatic hammer,* which gives excellent results in the hands of an expert.

100. Examples of Surfaces.—An example of concrete facing containing an aggregate of trap rock and having a

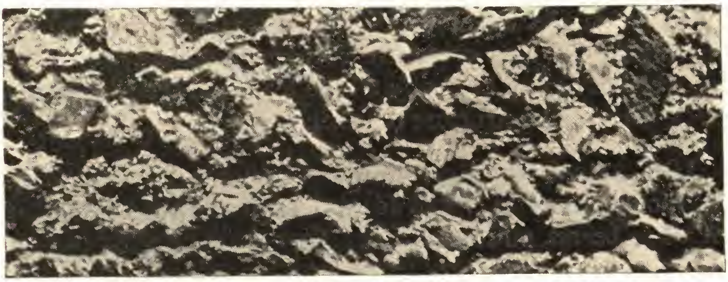


Fig. 33

brushed surface is shown in Fig. 33. A surface dressed with a pneumatic hammer is shown in Fig. 34. The effects obtained

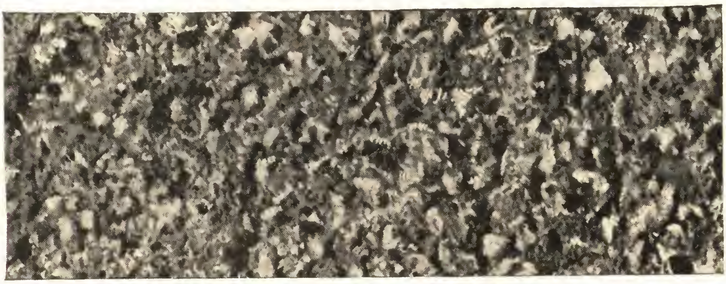


Fig. 34

by the use of the bush hammer or the ax are about the same as those obtained with the pneumatic hammer, but are not quite so regular and uniform in texture.

REINFORCED CONCRETE

101. General Explanations. — Reinforced - concrete structures are structures built of concrete in which steel has been embedded to add tensile strength to the concrete. The amount of metal used is generally small in proportion to the amount of concrete. In this type of construction *the steel and*

the concrete are so placed and combined that either, if left alone, would sustain but a small fraction of the load which they will carry when combined. There are other forms of construction in which concrete and steel are used in combination but which are not of reinforced-concrete construction. In one form the steel carries all or practically all the load, the concrete serving merely as a protective coating. In another form the concrete carries all or nearly all the load, and the steel is used to tie parts of the structure together.

102. Uses of Reinforced Concrete in Building. Reinforced concrete is well adapted for use in the construction of walls, beams, girders, columns, floor slabs, or other parts of the structure which carry the loads. It is also an economical material, and entire buildings are built of it, such as warehouses and factories where appearance is a secondary consideration. It is also employed in constructing buildings that are artistic, but such work is not particularly economical since these results can be obtained only by the use of expensive materials, expert workmanship, and with the greatest care in the construction. The use of reinforced concrete for artistic construction is nevertheless rapidly increasing, especially in the erection of high-class residences, schools, etc.

STRENGTH OF CONCRETE

103. In considering the strength of concrete, the forces acting in the various parts of a building that are constructed of concrete should be understood. These forces are known as *tension, compression,* and *shear.*

Tension is a force which tends to pull a body apart. It is resisted by the *tensile strength* of the material. *Compression* is a force that tends to crush or push together a body or mass of material. This is resisted by the *compressive strength* of the material. *Shear* is produced by two forces acting in opposite directions in a manner similar to the two blades of a pair of shears. These forces tend to push one portion of a body past another part, thus dividing it. The forces mentioned are gen-

erally the result of direct loads applied to the various columns, piers, girders, and beams.

104. In the case of steel, the compressive and tensile strengths are approximately equal. In concrete, the compressive strength is from six to ten times as great as its tensile strength. In other words, it requires from six to ten times the load or force to destroy it by compression that it does to break it by tension. The resistance of concrete to shear is also quite small.

105. The compressive strength of concrete is therefore its most important one and this can be determined by testing cubical or cylindrical specimens of the concrete. After these have been made and allowed to harden for a certain time, such as 28 days, they are tested in suitable machines by crushing or compression. The load or force required to crush each is noted and is then divided by the horizontal cross-section of the specimen in square inches and the number of pounds per square inch required to crush it is obtained. The crushing strength increases with the age of the concrete and with the increase in the proportion of cement used in making it.

TABLE II

TABLE OF CRUSHING STRENGTH OF DIFFERENT MIXTURES OF CONCRETE, IN POUNDS PER SQUARE INCH

Aggregates	1 : 1 : 2	1 : 1½ : 3	1 : 2 : 4	1 : 2½ : 5	1 : 3 : 6
Granite, trap rock	3,300	2,800	2,200	1,800	1,400
Gravel, hard limestone and hard sandstone	3,000	2,500	2,000	1,600	1,300
Soft limestone and sandstone	2,200	1,800	1,500	1,200	1,000
Cinders	800	700	600	500	400

106. In Table II the average crushing strength of various mixtures of concrete, in pounds per square inch, is given. The specimens tested were cylinders 8 inches in diameter and 16 inches long, and the age of the concrete was 28 days.

The figures here given were determined by the Joint Committee appointed by the American Society of Civil Engineers,

the American Society for Testing Materials, the American Railway Engineering Association, the Portland Cement Association, and the American Concrete Institute. This committee recommends that concrete used in construction should not be loaded more than a certain fraction of the ultimate, or crushing, strength indicated in the table. Building codes, in general, do not make the distinction between the various coarse aggregates that are given in this table nor do they give the ultimate crushing strength of the concrete. Instead, however, they give the load that is permitted, called the *safe load* per square inch, for concrete formed with different proportions of ingredients. For example, the New York Building Code contains the following:

Concrete in Compression	Safe Load per Square Inch
Concrete, Portland cement, 1 : 2 : 4	500 lb.
Concrete, Portland cement, 1 : 2½ : 5	400 lb.

From this it will be noted that the 500-pound load is 22.7 per cent. of the crushing load given in Table II for trap-rock concrete having the same proportions of ingredients; and the 400-pound load is 22.2 per cent. of the crushing strength of concrete of similar proportions and like material. Thus, in practice, the safe load for concrete is taken as a little more than one-fifth of the crushing strength shown in 28-day tests.

107. Advantages of Reinforced Concrete.—Reinforced concrete buildings, when properly designed and built, are very strong. They can be erected at a reasonable first cost and the cost for upkeep is low. They are therefore looked upon with favor in purely commercial enterprises.

Buildings formed of this construction are less affected by vibrations and shocks than some other types, because they are so firmly knit together that they are not easily disturbed. They are particularly adapted to regions subjected to earthquake. They have the additional advantage of being fireproof, dampproof, and vermin-proof, thus protecting their contents from injury by fire, water, or rodents.

THEORY OF REINFORCED-CONCRETE CONSTRUCTION

108. Classes of Members.—Reinforced-concrete buildings are formed of walls, columns, piers, girders, beams, and slabs. These members may be grouped into two classes,

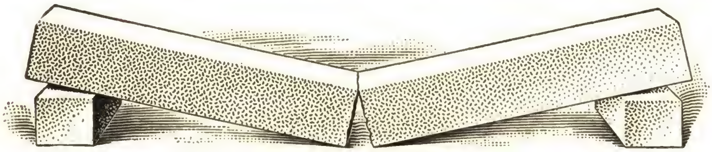


Fig. 35

namely, *columns* and *beams*. Under the heading *columns* may be placed vertical supports such as columns, piers, and walls, and under *beams* all horizontal members such as girders, beams, and floor and roof slabs.

The principles used in designing these two classes of members are very different, and will be merely illustrated in this Section, but will be more fully discussed in the Sections *Design of Columns* and *Design of Beams*.

109. Beams.—All the horizontal members of a structure, such as girders, beams, and floor slabs, are virtually beams. The stresses acting in loaded beams can be shown by experiment. Thus, if, as shown in Fig. 35, a concrete beam, without steel reinforcement is loaded until it fails, or breaks, it will in all probability break as shown in this figure. The lower portion will be pulled apart due to limited tensile strength of concrete.

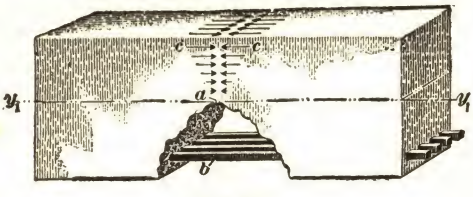


Fig. 36

110. Now if a sufficient number of steel rods are introduced near the lower surface of the beam, as shown at *b* in Fig. 36, the tendency to pull apart in its lower portion, when the beam is loaded, will be overcome. The effect of a load on

a beam is to produce compression in the upper portion of the beam as indicated by the arrows *c*, and tension in the lower por-

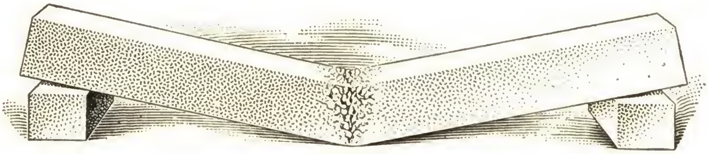


FIG. 37

tion, which is neutralized by the steel rods. The concrete has considerable compressive strength and resists strongly any tendency to crush it. In a well-designed beam, the crushing strength of the beam above the line $y_1\ y_1$ will be balanced by the tensile strength of the steel below the same line.

111. If there is more tensile strength provided in the steel reinforcement than there is crushing strength in the concrete, and the beam is loaded until it breaks, it will fail by crushing at the top, as illustrated in Fig. 37. It will require, however, a much greater load to break the beam in this case than in the case shown in Fig. 35, thus demonstrating that the reinforcement adds much to the strength of the beam.

The designing of reinforced-concrete beams consists of supplying the proper proportion of reinforcing steel and concrete so that under a maximum load, the steel will not fail by tension before the concrete fails by compression, and vice versa.

112. When the concrete and the steel are under about the same stress, the beam, if heavily loaded, will sometimes stretch

FIG. 38

the steel excessively and the concrete will develop small cracks such as shown at *a* in Fig. 38.

113. Columns.—In columns, reinforcement is not absolutely necessary, as concrete is strong in compression. It is,

nevertheless, good practice to use reinforcement, because the steel makes the column safer to use and also increases its carrying capacity. A smaller reinforced column will therefore do the work of a larger one not reinforced and will occupy less space. This reduction in size is due to the fact that the strength of the steel rods encased in concrete in resisting compression is very great. Even a small amount of steel thus embedded will support a considerable load and permit of a reduction in the concrete area required. The arrangement of reinforcement in columns will be shown later on.

114. Design of Reinforced-Concrete Buildings. The complete computations required for the design of reinforced-concrete beams and columns are complicated and the architect therefore usually entrusts this part of the work to engineers who have made a specialty of reinforced-concrete work. It is, nevertheless, important for the architect to know the principles involved in the design so that he can arrange the architectural features of a building harmoniously with the engineering features, and also so that he can tell in the field whether or not the principles of good construction are faithfully followed. For this reason, the following articles will be devoted to a brief description of the best types of reinforced-concrete building construction and the principles upon which these types are based.

In making the preliminary plans, the architect should make provision for columns having a somewhat larger area than for steel columns that carry equal loads. He should also provide in the height of the stories for the greater depth of beams and girders that are required in reinforced-concrete construction.

REINFORCEMENT

REINFORCING MATERIALS

115. Quality of Steel.—Steel selected for reinforced concrete should be of a quality that is suitable for this purpose. It may be advisable in small structures to obtain the steel from a local stock, even though the quality of the steel is not the best; for large structures, however, the quality of steel desired is usually specified and the order is filled at the rolling mill, or it may be taken from stock that has been proved by tests to conform to the specified requirements.

116. The specifications generally followed in describing reinforcing steel are those of the American Society for Testing Materials, which recognizes two different kinds of steel, namely, *billet steel* and *rerolled steel.* **Billet steel** is made from new billets or blocks which are rolled out to the required shape. There are three varieties of this steel, known as *structural, intermediate,* and *hard* steel. **Rerolled steel** is made from old railroad rails that are split and heated and passed through rolls in order to form them into the proper shape. There is only one grade of rerolled steel and it has properties similar to those of the hard grade of billet steel. Owing to its brittleness, which is especially pronounced in frosty weather, hard steel and rerolled steel are adapted only for structures that are not subject to shocks or vibrations and in which the rods or bars do not require much bending.

Specifications for reinforcing steel frequently require that samples be taken from the various shipments of steel, after they have been received at the building site, and tested to prove that the steel is of the quality required. This is done by employes of a testing laboratory.

117. Allowable Stress in Steel.—Steel is considered as being able to sustain safely a tensile force of 16,000 pounds per square inch. The safe compressive strength of steel is taken to be 10,000 pounds per square inch.

This compressive strength of steel is about 15 times the safe compressive strength of concrete, which is considered to be from 650 to 750 pounds per square inch.

118. Forms of Reinforcement.—Steel reinforcement for concrete construction may be in the form of loose rods or bars, rods or bars that have been secured together into shapes known as *units,* sheet metal which has been expanded into what is known as *expanded metal,* and wires that have been woven or welded together to form what is known as a *fabric.*

The loose rods or bars may be used as a reinforcement in any of the structural parts of the building. The units are used only in the beams, girders, and column construction; and the expanded metal, perforated metal, and fabrics, in the wall and floor construction. The forms of these reinforcing members are described later on in this Section.

BARS AND RODS

119. Forms of Bars.—Steel bars and rods for reinforcing concrete may be either plain or deformed. Plain bars are

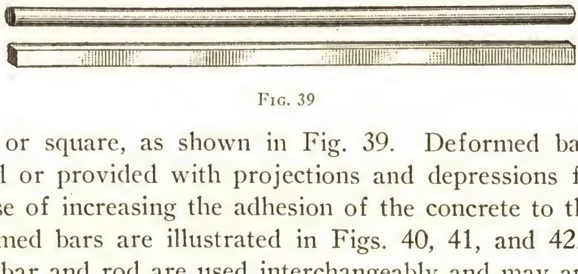


Fig. 39

round or square, as shown in Fig. 39. Deformed bars are twisted or provided with projections and depressions for the purpose of increasing the adhesion of the concrete to the bar. Deformed bars are illustrated in Figs. 40, 41, and 42. The terms bar and rod are used interchangeably and may apply to round or square bars, either plain or deformed.

Fig. 40

Many buildings in this country have been built with plain bars and practically all work done in foreign countries has been erected with plain bars only. Most American engineers, however, prefer the deformed

bars as offering additional safety at a very small increase in cost.

120. Adhesion Between Concrete and Steel.—A steel bar embedded in concrete offers considerable resistance to being pulled out. This resistance is due to the adhesion between the concrete and the bar. The adhesion of the concrete to steel bars is naturally increased by deforming the bar, and a smaller deformed bar will do more work than a larger plain bar.

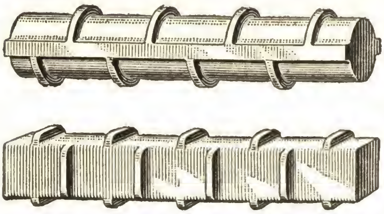


Fig. 41

121. To test the adhesion between steel bars and concrete, specimens such as shown in Fig. 43 are prepared, consisting of a block of concrete in which a steel bar of the kind to be tested is embedded, with one end projecting as shown. The test consists in pulling the bar out of the concrete block and noting the force required to do so. If, in testing different kinds of bars, two bars of equal diameters and equal lengths of embedment show different resistances against efforts to pull them out, the conclusion is naturally drawn that the bar requiring the greatest pull adheres best to the concrete and is therefore the one to be preferred in practice.

Many tests of the kind described have been made and have showed that the adhesion is greatest when a rich mixture of concrete is used; that the adhesion is greatly increased when care is used in preparing and storing the specimens and especially when the concrete is kept moist during its hardening period so as to furnish sufficient water for the cement to set properly; and that it is very important that the bars be embedded in large blocks. Therefore, in actual construction the concrete should be properly proportioned, carefully placed, and kept moist until hard, in order to develop the greatest adhesion; and also

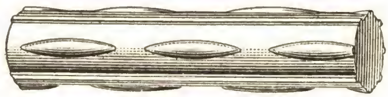


Fig. 42

the bars must be kept away from the immediate surface of the concrete member in which they are embedded.

122. Deformed Bars.—Of the many deformed bars obtainable in the market, only a few will be mentioned as typical of various designs.

The **Ransome bar,** Fig. 40, is made by twisting a plain square bar in a cold state. The sliding resistance of the bar is increased by the spiral ridges along the surface of the bar. These bars are made of soft steel, are easily bent on the job, and make good reinforcement.

123. Hot-twisted bars are rerolled bars twisted in a hot state. They are usually very hard and very brittle and should not be used without careful testing to insure the quality. They may be recognized by being covered by so-called *mill scale,* which is a metallic coating formed in scales upon the surface of all bars when they leave the mill. This mill scale drops off the cold-twisted bars in the twisting process.

124. Corrugated bars are shown in Fig. 41. These bars are formed with projections on all sides which extend into the surrounding concrete and obtain a firm grip.

125. Havemeyer bars are made round, square, and **I** beam in shape. They have longitudinally extending fins or projections giving the bar a wavy outline in profile. In Fig. 42 is shown a round bar of this design.

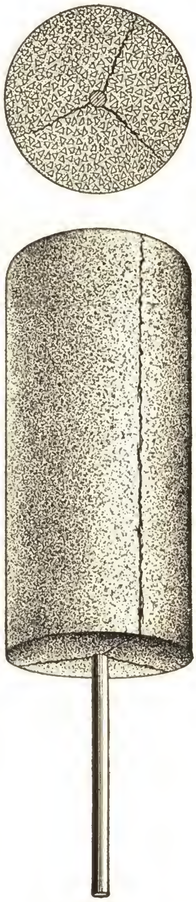


FIG. 43

126. Trussed bars, also known as *Kahn bars,* are made from bars having at two opposite sides flat extensions as shown in Fig. 44 at *a*. These extensions are sheared along part of

their length so as to separate them from the body of the bar for considerable lengths, only short spaces of connection being left at intervals. The sheared portions *b* are bent to form prongs or projecting parts as indicated in Fig. 45. These projecting parts serve to increase the adhesion of the bar to the concrete, and also act as reinforcement of the concrete, to resist the action of shear.

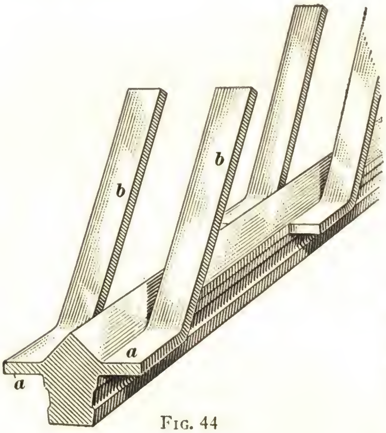


FIG. 44

There are many other kinds of deformed bars on the market all of which possess some particular point in their favor.

127. Units.—Bars intended for the reinforcement of beams and girders are sometimes assembled at the mill in the form of frames called **units.** The advantage of forming the reinforcement into a


FIG. 45

unit at the mill is that the various bars are properly placed and held in position more accurately than they might be if built at the building. The bars are fastened together and when set in


FIG. 46

the form they are all in the proper relation to one another and in such a position that they will be most effective in resisting the various stresses in the beam or girder. An example of a unit designed for use in a girder is shown in Fig. 46.

128. Spirals.—For columns, reinforcement in the form of spirals or hoops such as shown in Fig. 47 (*a*) is also made at the mill in a *unit,* consisting of the spiral stiffened by the vertical members *a*.

129. Both the units for girders and the spirals for columns are frequently made so that they can be folded flat for convenience in shipping. When they are to be used in the building they are expanded to their proper shape and set in the forms. A collapsible spiral reinforcement unit for a column is shown in Fig. 47. In (*a*) is the expanded unit, in (*b*) is a view of the unit collapsed, and in (*c*), a side view of the collapsed unit.

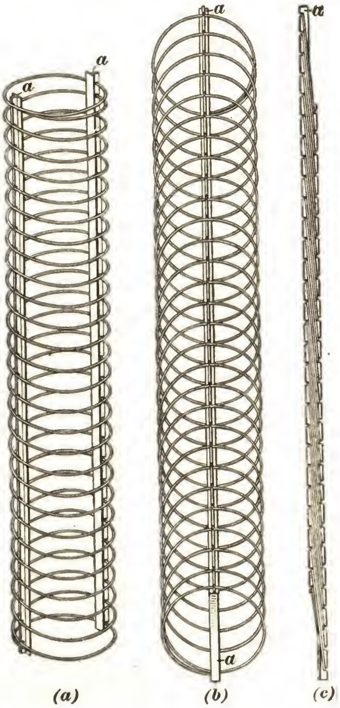


Fig. 47

EXPANDED METAL

130. The form of sheet-metal reinforcement known as **expanded metal** is shown in Fig. 48. This material is made in sheets of short lengths that are easily put in place. They must be lapped, however, wherever they meet. The meshes, or diamonds, are formed in different sizes and the metal is made in different thicknesses according to the purpose for which the reinforcement is to be used. The 3″×8″ mesh, or opening, is commonly used in reinforcing floors in buildings and the 6″×12″ mesh is used for sidewalks. The manufacturers' catalogs give the various thicknesses, mesh sizes, and strengths of the different patterns of expanded metal when used for different floor spans and with various mixtures of concrete.

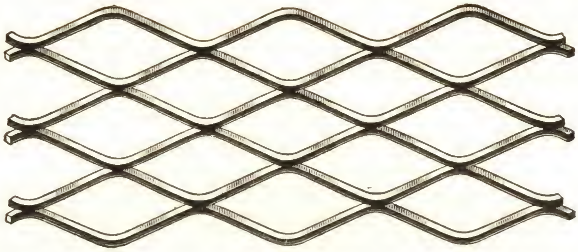


Fig. 48

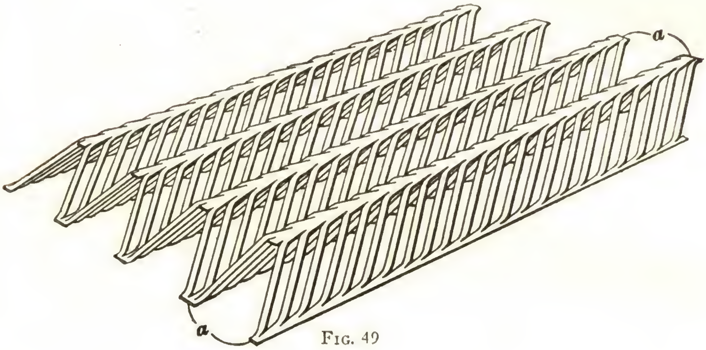


Fig. 49

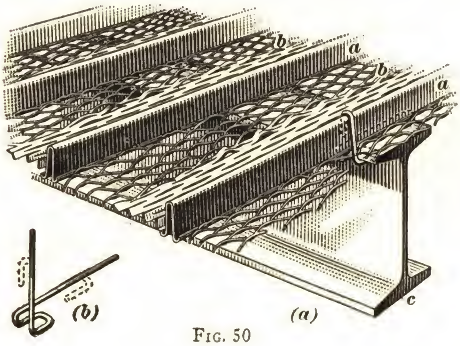
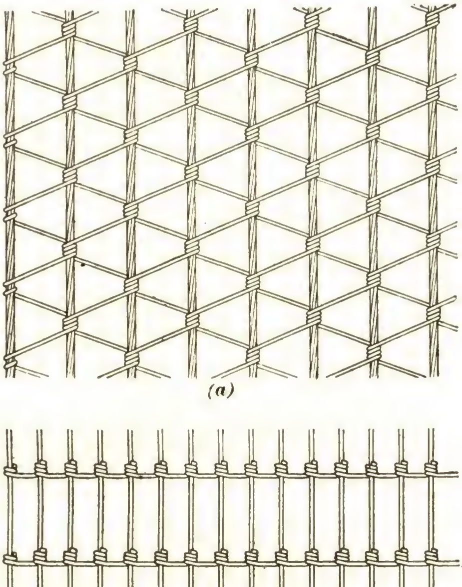


Fig. 50

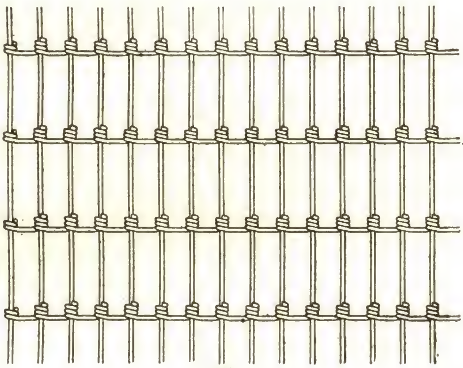
In laying out expanded-metal reinforcement, the long dimension of the diamonds should always be placed in the direction of the shortest span. The ends of the sheets should be lapped the length of one diamond and the sides the width of one diamond.

131. A form of expanded metal that is used for reinforcing thin slabs of concrete, such as are used for roofs and very light floors, is shown in Fig. 49. This consists of what is called herring-bone lath, bent at the ribs, thus making a sheet that is quite stiff. This product is known as *Trussit*.

132. There are many other forms of expanded metal and metal lath on the market; many of these can be used in concrete work without forms, the metal being stiffened by ribs so that it will support the weight of a light concrete slab. Such materials are known as *self-centering*, because no centers, or forms, are required. In this form of reinforcement a sufficient amount of the concrete passes through the meshes to secure the necessary adhesion between the steel and the concrete. By this bonding of the materials, the steel provides the necessary tensile



(a)



(b)

FIG. 51

strength to resist the stresses due to the loads in the structure.

One form of self-centering reinforcement is shown in Fig. 50. It has standing ribs *a,* and between them are expanded-metal panels *b.* This lath is shown supported by steel beams *c.* In (*b*) is shown the form of the clip with which the sheets are fastened to the beams to prevent displacement during the concreting.

WIRE FABRICS

133. For reinforcement of slabs, what are called *wire fabrics* are frequently used. These are made by weaving or welding together wires or rods into meshes having rectangular or triangular shapes.

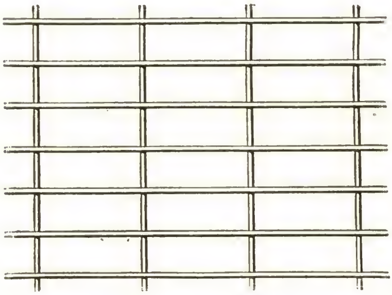


FIG. 52

A woven-wire fabric having a triangular mesh is shown in Fig. 51 (*a*). The reinforcing parts of the fabric are the heavy members, which consist of several small wires twisted together in the form of cables.

A fabric of similar design is also made by using heavy wires or round rods instead of cables for the main reinforcing parts. These heavy strands or rods must be placed in the direction of the span, and the lighter wires serve as secondary reinforcement.

In Fig. 51 (*b*) is shown a fabric formed of wires that have been woven together into rectangular-shaped meshes.

In Fig. 52 is shown a rectangular mesh formed by welding the wires together. By this means of fastening, a solid and substantial union between the wires is obtained. Meshes of this form are made in different sizes, and fabrics are formed of different sizes of wires to meet the requirements of the loads that are to be carried.

Woven and welded wire fabrics are made in long lengths and are received at the building in rolls. They waste less material than sheets of expanded metal, as a slight lapping is suffi-

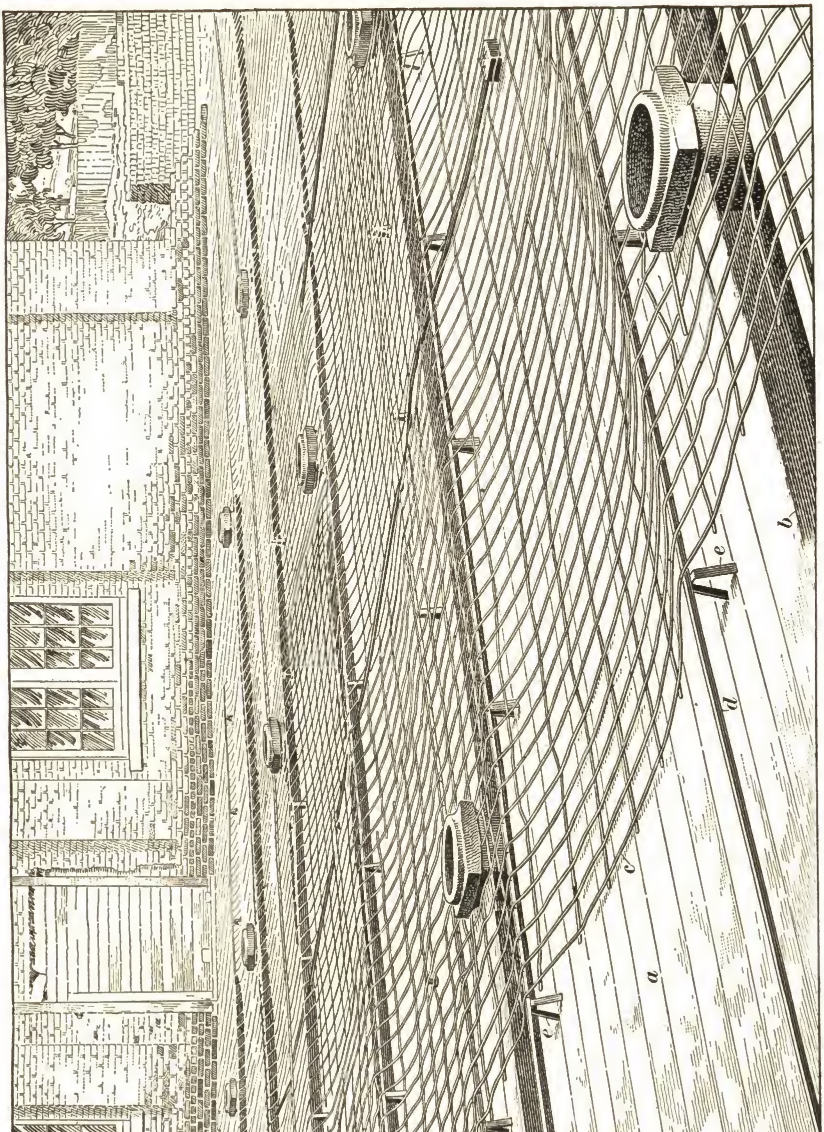


Fig. 53

cient to bond the reinforcement together, and fewer lappings will be required.

134. Fig. 53 illustrates the practical application of welded-wire rectangular-mesh fabric to a reinforced-concrete floor. The form work *a* extends between the beams *b*. The fabric *c*, which extends with the heavy wires spanning from beam to beam, is raised over the beams and droops between them nearly to the bottom of the slab, or nearly to the surface of the forms. This is accomplished by supporting the fabric upon rods *d*, one on each side of each beam. These rods extend parallel with the beams, and are held up by small iron chairs *e* fastened to the forms. When the concrete has been placed and has hardened, the forms are removed, leaving the chairs and rods in place within the concrete.

APPLICATION OF REINFORCEMENT

COLUMNS

135. Columns are reinforced either *vertically* or *laterally*, or both together. In the vertically reinforced columns the reinforcement is placed as in Fig. 54, where *a* is the concrete and *b* the reinforcement. The rods are placed as near as possible to the outer faces of column, with only enough concrete outside of the reinforcement to afford fire protection. The rods are held in the proper relative position by means of wire ties *c*, placed from 6 inches to 18 inches apart.

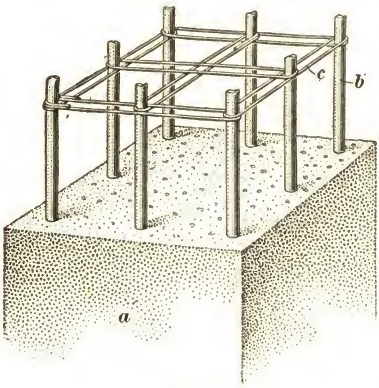
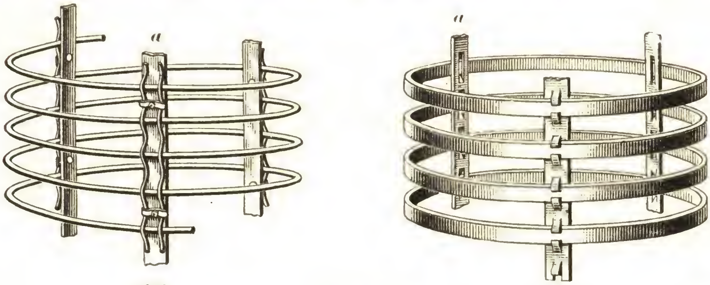


Fig. 54

In *laterally reinforced* columns, the hoop reinforcement, such as is illustrated in Fig. 55, is employed. The hoop reinforcement may be in spiral form as in (*a*) or may consist of a series of independent

bands as in (*b*). Both the spirals and the hoops are held at a fixed distance apart by means of separators, or spacers, *a*.



(*a*) FIG. 55 (*b*)

136. Effect of Hoops.—The strengthening action of column hoops will be understood from Fig. 56. If a vertically reinforced-concrete column be loaded until it breaks, that is, until the concrete crushes, it will take the appearance indicated, the vertical rods *a* buckling between the ties *b*. But if the ties are closely spaced, as in a hooped column, the concrete cannot escape sidewise, being held in by the hoops. The hoops furnish a jacket for the concrete and prevent it from escaping sidewise, thus increasing the safety of the column. All hooping of columns should have an outside covering of concrete 2 inches thick for protection from fire and corrosion.

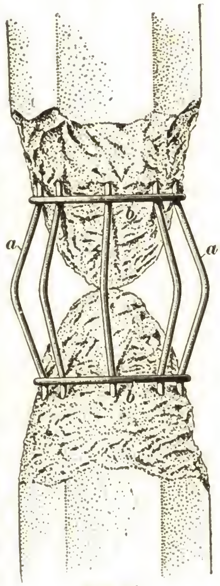


FIG. 56

The hooped form of reinforcement is considered stronger than the vertical form, for the same amount of metal used. The spacers in the hooped reinforcement have a certain value as straight reinforcement and in some cases more straight reinforcement is added to the hooped reinforcement to give more strength to the column.

As was shown in Fig. 47, this hoop reinforcement is made in units and can be folded together when shipped and opened up into the proper shape when set in position.

BEAMS AND FLOOR SLABS

137. Since steel is used principally to resist the tension stresses in beams, and since these tension stresses are located at the bottom of the beam, the steel must be placed at the lower side of all beamlike structures. The depth of a beam is measured from the top of the concrete to the center of the steel at the bottom, and the deeper a beam is, the greater is its strength. It is therefore desirable to have the steel as close to the bottom of the beam as possible in order to have a beam of the greatest possible depth and therefore of the greatest possible strength. There is, however, a limit beyond which it is not advisable that the steel approach the bottom of the beam. This depth is determined by the following considerations:

1. *Adhesion must be developed* between concrete and steel, and this is possible only when a proper amount of concrete surrounds the steel. If no adhesion were present, the steel and concrete would not act in unison and assist one another, and the beam would fail.

2. *The steel must be protected against fire.* If the heat should penetrate the concrete far enough to soften the steel, the beam would fail.

3. *The steel must be protected against corrosion.* If moisture and air should reach the steel and cause it to rust, the steel would in time become eaten up and the beam would fail.

For these reasons, concrete must surround all the reinforcement. It is customary to cover the steel of beams with $1\frac{1}{2}$ inches, and the steel of girders with 2 inches, of concrete. Where the reinforced-concrete work is especially exposed, as when near water, and especially near salt water, these dimensions should be increased.

138. Stirrups.—While it may not be easy to understand why stirrup bars are required in beams, experience shows that even though a beam contains sufficient steel in the main tension rods already referred to, it may fail by small cracks opening up in the manner indicated in Fig. 38. These small cracks may be prevented by the addition of the reinforcement

indicated in Fig. 57, the additional reinforcement being so placed as to extend into the body of the beam, as in (*a*), in

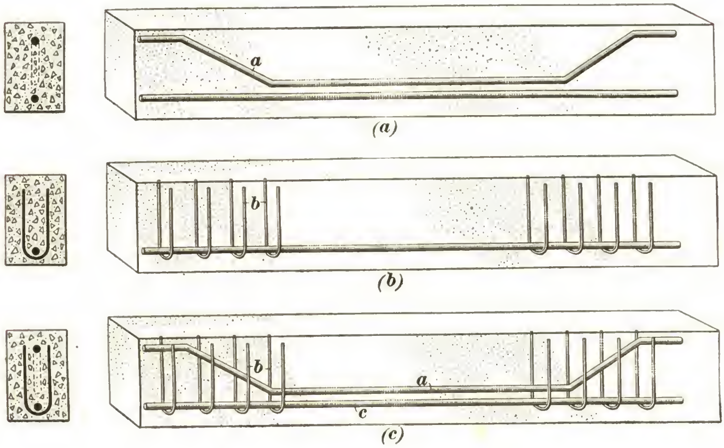


Fig. 57

the shape of bent rods *a*, or, as in (*b*), in the shape of light auxiliary rods *b* encircling at their bottoms the main tension rods. These auxiliary rods because of their shape are known as *stirrups* or **U** *bars*. In the best types of construction, both the straight rods and the stirrups are combined as in (*c*), where straight bars *c* and bent bars *a* extend from end to end, in conjunction with **U** bars *b* as shown.

139. Forms of Concrete Beams.—There are two kinds of reinforced-concrete beams; namely, *rectangular beams*, as shown in Fig. 58 (*a*), and **T** *beams*, as shown in (*b*). It has already been explained that a plain-concrete beam, such as shown in (*a*), may break by its tensile resistance at the bottom being overcome. By the addition of steel reinforcement to strengthen the bottom, a reinforced-concrete beam is obtained that will

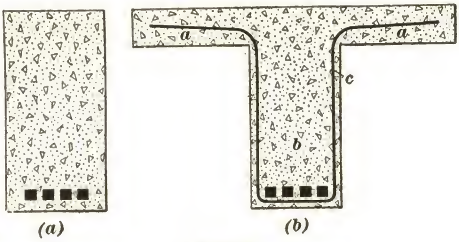


Fig. 58

break only under greater loads and by compression in the top. Since this beam has its weakest point at the top, it is desirable to strengthen the top and thereby the entire beam. This may best be done by increasing the concrete at the top. The concrete is increased, as in (*b*), by adding a flange *a* to each side of the rectangular web *b*, which is usually part of the floor slab between the beams. A beam so constructed is much stronger than the rectangular beam shown in (*a*) and is known as a **T** *beam*.

140. Construction of Concrete Beams.—The **T** beam is a feature of reinforced-concrete building construction which makes for great economy. A reinforced-concrete floor consists usually of beams and of floor *slabs* between the beams. It has been found entirely feasible to unite the floor slab and the beams so that each and every beam becomes a **T** beam, and the flanges of these **T** beams are obtained at no expense whatever, since the slab must be made in any event, to form the floor. The only requirement is that the flange shall be well tied to the web, as otherwise they cannot be counted upon to act in unison, that is, the slab will not act as a flange unless well tied to the web. This result is obtained by two expedients, namely, by extending the stirrups *c* so that they project well into the slab *a*, and by so placing the concrete that there is no plane of cleavage or separation between slab and web of the beam. In other words, the concrete of slab and beam is poured in one operation, so as to form one solid mass after hardening. Concrete so poured as to form one mass is called **monolithic** concrete, the meaning of the word monolithic being *one stone*.

EXAMPLES OF REINFORCED-CONCRETE CONSTRUCTION

141. Typical Exterior.—The typical reinforced-concrete building in course of construction, illustrated in perspective in Fig. 59, combines the several elements already described. This building is a warehouse of the type of construction known as skeleton construction. In this construction the exterior con-

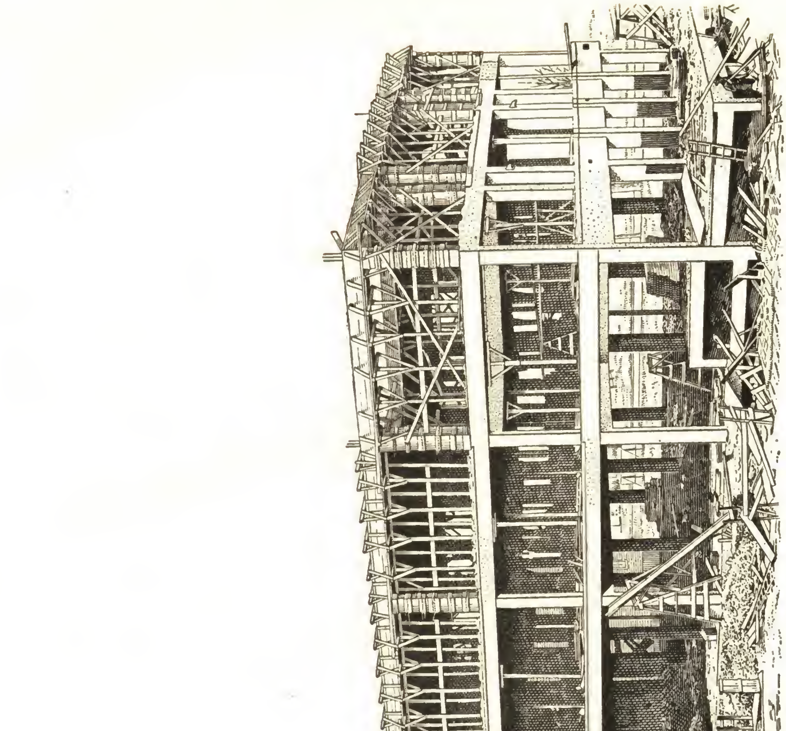


Fig. 59

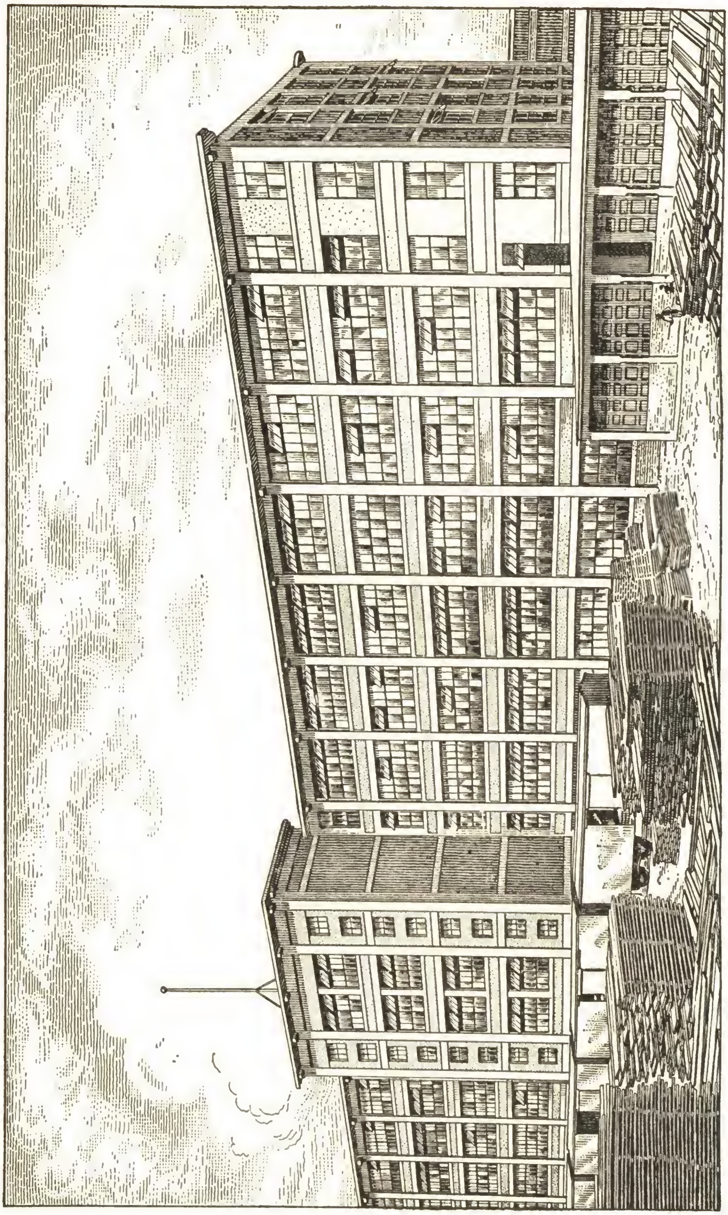


Fig. 60

sists entirely of vertical piers or columns *a* and horizontal beams and girders *b*. The openings will subsequently be filled with walls up to the window-sill levels, and with sash. The beams *b* are made strong enough to support these fillings as well as a portion of the floor loads. The building when finished will present a neat and useful appearance but will not be a particularly pleasing structure from an architectural point of view.

142. In Fig. 60 is shown a completed building similar in construction to the one in Fig. 59. The same pier and girder construction will be noted, but the spaces between the piers and girders have been filled up. In most of these spaces the filling consists of a brick wall from the girder up to the window sill and a glass enclosure above. Some of the spaces, as on the side of the projecting wing, are filled entirely with brickwork. A building of this character is for utilitarian purposes entirely, space and light being the main objects sought for.

143. A **typical interior construction** is shown in perspective in Fig. 61 (*a*) and in sectional elevation in (*b*). This illustration shows a reinforced-concrete column which supports reinforced-concrete beams and girders. Over the beams and girders extends a floor of reinforced concrete which is monolithic with the beams and girders and is called the *slab*. The concrete is indicated partly broken away in (*a*) to show more clearly the main tension rods *a* and *b* of a beam, rod *a* being straight and rod *b* bent. These rods are encircled by stirrups *d*, and other stirrups are similarly disposed in the concrete of the main girder. The ends of the reinforcing rods of the main girder can be seen, and the ends of the reinforcement of the slab are shown projecting beyond the edge of the slab. The sectional elevation (*b*) shows more clearly the reinforcement of the main girders over the column, and especially how the bent rods of the girder are continued into the adjacent span as at *c*. The purpose of extending the rods *c* into the adjacent span is twofold: first, to tie the several parts of the building together, and second, to resist certain tension stresses which experience shows exist in the girders over the tops of the columns. A similar arrangement is used in the beams where these cross

over the tops of the girders. The general system of reinforcement in floors of the type here shown is therefore to have, in all parts, certain straight rods and certain bent rods, the straight rods being near the bottom of the member throughout their

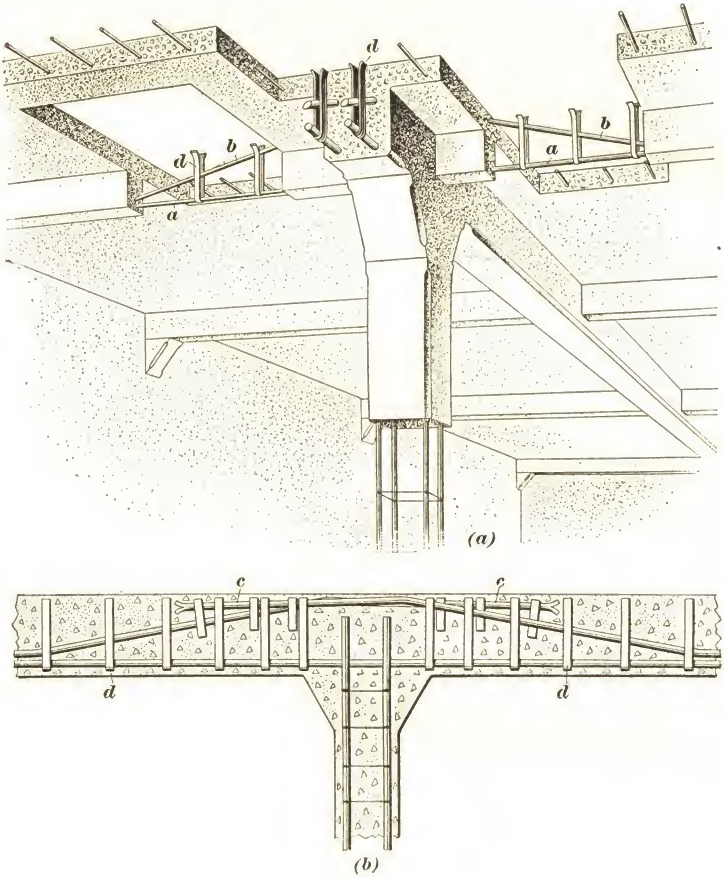


Fig. 61

length, and the bent rods being near the bottom of the member at the center of the span, and raised over the supports at the ends of the span. A building constructed on the principle shown in Fig. 61 is said to be of a *slab-and-beam construction.*

144. Tile-Concrete Floors.—While a great many buildings of the slab-and-beam type have been erected, the forms needed for their construction are complicated, and the finished ceilings are broken up by the beams and girders. The construction may be somewhat simplified by using longer spans so as to dispense with some of the beams. But, the longer the span, the thicker the slab must be, and consequently the more heavy and expensive.

In order to lighten the slabs and thereby cheapen the construction, the floor system shown in Fig. 62 is used. In this the slab consists of a number of small beams separated by hol-

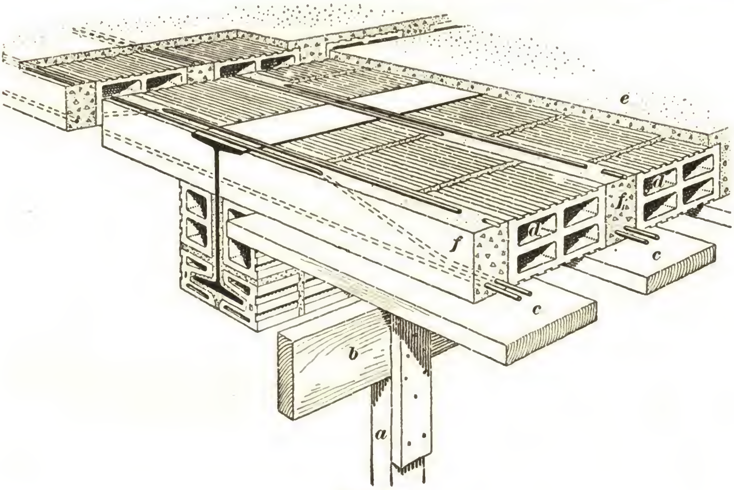


Fig. 62

low tiles, with a thin concrete slab extending over the tops of the beams and the tiles. Floors of this kind, known as *combination tile-concrete floors,* are very useful where no heavy loads are to be carried.

145. Flat-Slab Floors.—In the so-called *flat-slab floors* the beams and girders are dispensed with altogether. The floor consists merely of a flat slab which, as indicated in Fig. 63, rests directly upon the columns. This type of floor is also often called a *mushroom* floor because the columns are generally flared at the top and suggest the appearance of mush-

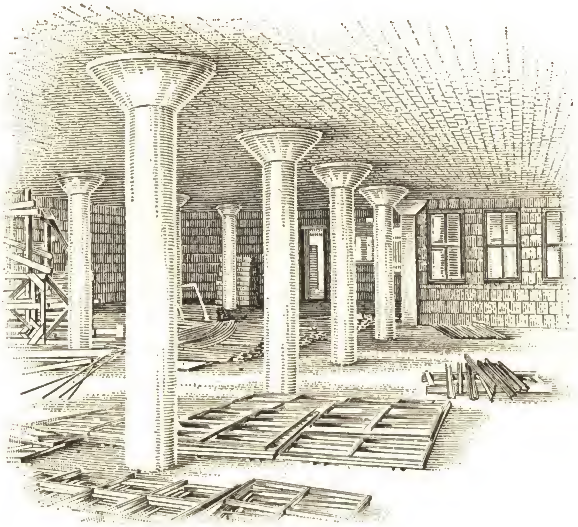


Fig. 63

Fig. 64

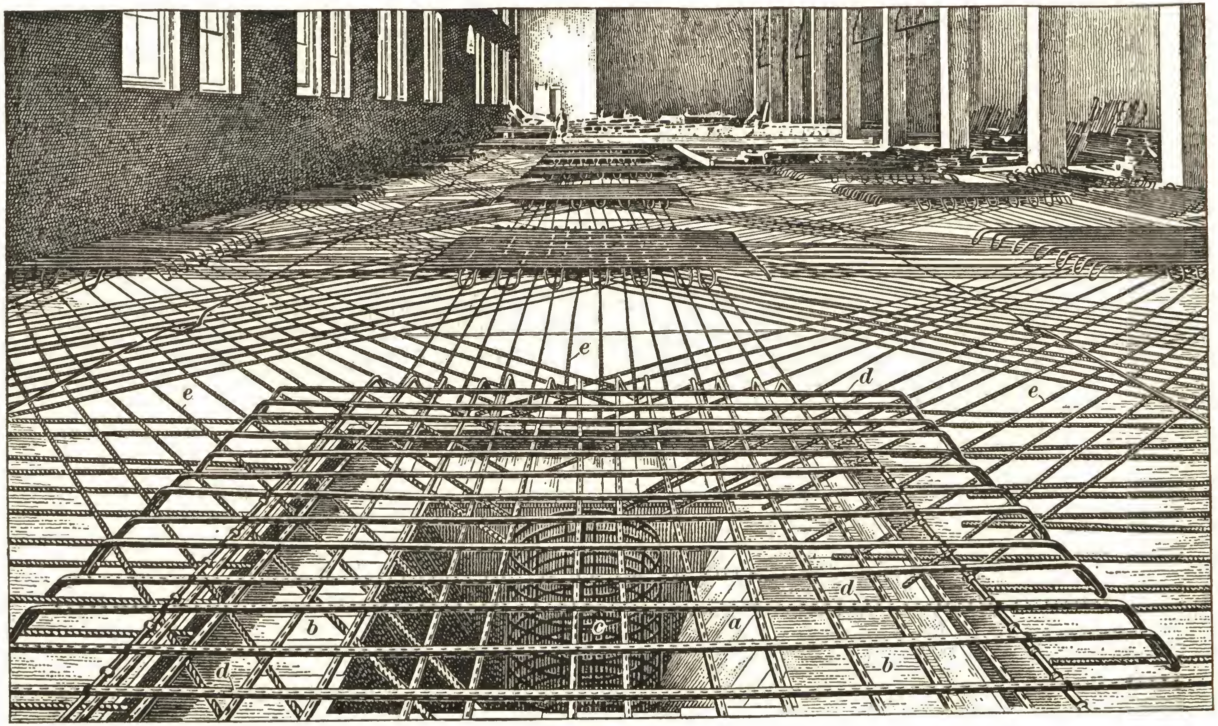


FIG. 65

rooms. Often the cap is surrounded by a thickened portion of the floor called a *drop panel,* as shown in Fig. 64. Drop panels are most common in heavy construction, such as is used in warehouses. The general arrangement of the reinforcement is shown in Fig. 65. The form for the spread cap of the column below is shown at *a* and the form for the drop panel at *b*. Hooped reinforcement for the column *c* and heavy reinforcement *d* on the top of the column are also illustrated. The slab reinforcement *e,* which consists of lighter rods, extends diagonally and also in direct belts, from column to column. As is usually the case in reinforced-concrete construction, the reinforcement is near the bottom midway between supports and raised to near the top of the slab over the supports, so that the steel rods combine to form a so-called *mat* over each column.

FORMS FOR REINFORCED-CONCRETE STRUCTURES

146. General Features of Forms.—There are many different ways in which forms for reinforced-concrete structures may be built. The method used is generally dictated by the peculiar requirements of each case or the preference of the contractor.

Forms for reinforced-concrete structures often are of the same kind as those used for structures of plain concrete; as an example, the forms illustrated in Figs. 25 to 28 could be used equally well for construction of reinforced concrete.

147. Forms are expensive items in the construction of a reinforced-concrete building and it is therefore important that they be so designed and assembled that they can be easily removed and used many times without alteration. To facilitate this repeated use, the architect or engineer should design all floors so that the beams and girders are of the same size and location on as many floors as possible. An example of such design is shown in Fig. 59, where the same forms are being used on the third story that were used to cast the similiar parts of the lower stories.

It is true that beams and girders must be made stronger where heavier loads are to be carried and consequently it is not always feasible to adhere to one layout for all of the floors, but in many cases the forms may remain the same size, and the strength of the beam or girder be increased or decreased by an adjustment in the amount of the steel reinforcement that is used.

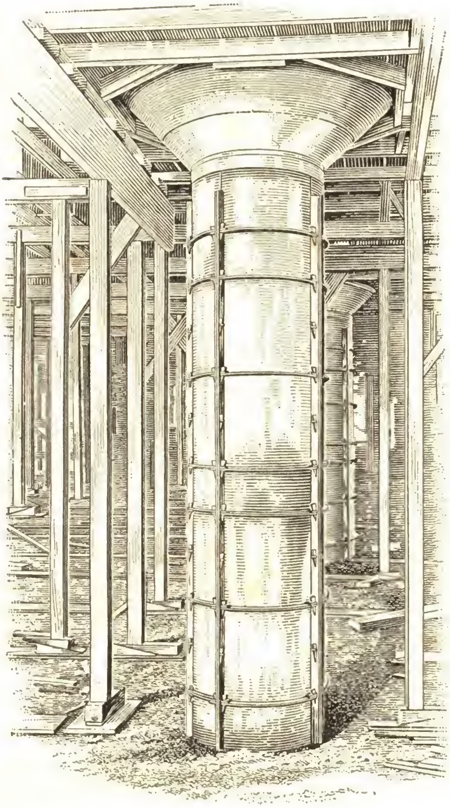


Fig. 66

148. Forms for Columns and Piers.—Concrete columns are usually cast either in a round, octagonal, or rectangular shape. The round or octagonal column is generally used where the floors are of the flat-slab construction, and hooped reinforcement is used in them.

Rectangular piers or columns are frequently used to support floors of the beam-and-slab type, and are generally used to support the outside wall construction, as the projecting corners are less objectionable along the wall than on the independent columns in the interior parts of the building.

149. Forms for Round Columns.—The forms for round columns are usually composed of light steel plates that have been previously bent to form the curves required. These

plates are held together by means of bands and vertical bars as shown in Fig. 66. The bands and bars are fastened together by means of steel wedges.

Round columns that support a flat-slab floor construction are usually formed with a circular cap as shown in the illustration. The form for this cap is also made of sheet metal, the top portion having a flange that is fastened to the wooden form of the floor construction and the lower portion having a collar that fits over the column form.

Forms of this type are usually patented and are rented from the manufacturer for the period of time required to complete the job.

By the use of metal forms as described, a concrete column is cast which requires very little if any refinishing, as the surface is smooth and free from defects such as are common when wooden forms are used.

150. Forms for Square Columns.—A wooden form for a square column, or pier, which carries a beam-and-slab floor construction is shown in Fig. 67. The sides of this form are composed of boards *a*, which are held together by means of battens *b*. The upper ends of these sides have rectangular openings into which the beam forms fit. By means of this construction the beam forms connect with the column forms so that when the concrete is poured a solid concrete framework is formed.

The sides of the column forms are nailed together at the corners but this is not sufficient to hold the form intact when the concrete is poured, consequently a system of strong braces is used for this purpose. The number of these braces and the frequency with which they are used is determined by the height and size of the column. Braces for columns having considerable height and a large area should be of heavy construction and located closely together, so that they may resist the pressure due to the wet concrete in the forms.

151. The form of brace shown in Fig. 67 is of the simplest type. It consists of four timbers *c* and *c′*, *d* and *d′*. Blocks *e*, *e′*

are secured to the under side of the timbers *c* and *c′*, respectively, and blocks *f* and *f′* are secured to the top of the timbers *d* and *d′*. These timbers are assembled around the column form as shown and nailed to the form sufficiently to hold them in place until the wedges are set and driven into place. These

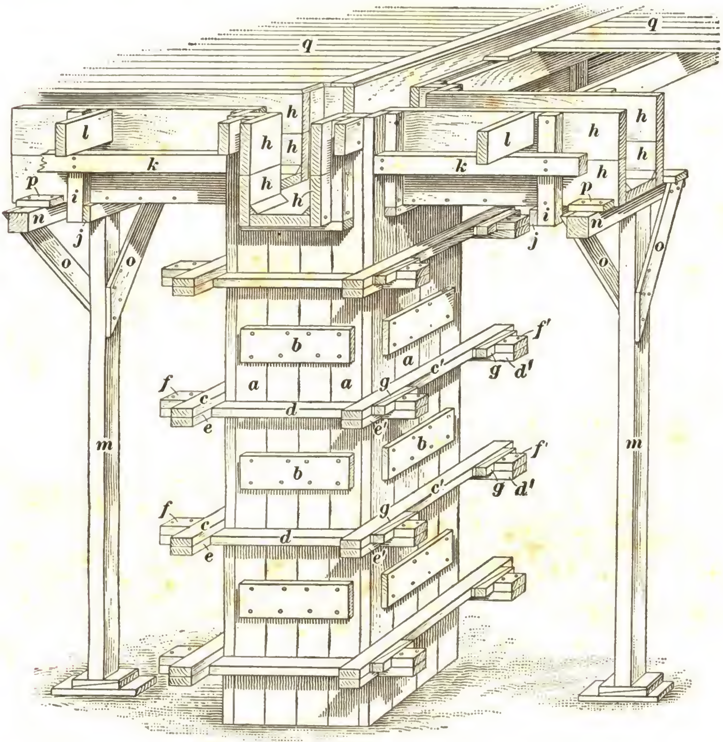


Fig. 67

wedges are used to draw the timbers into close contact with the column form.

There are many devices that are used for holding the column forms together. Some consist of metal bands, others of timbers with clamps attached, and some have bolts and wedges as shown in Fig. 19. They are all designed to be adjustable, so that after they are located in the position desired they can be tightened up and thus brace all parts of the column form.

152. In Fig. 68 is shown a device consisting of iron yokes *a,* which are attached to timbers. These devices are placed alternately on the sides of the column and thus brace all sides. In (*b*) the yokes are used to brace two sides of the column, and vertical timbers, as at *b,* are secured to the horizontal timbers shown and wedges *a* are driven into place until the braces are made rigid.

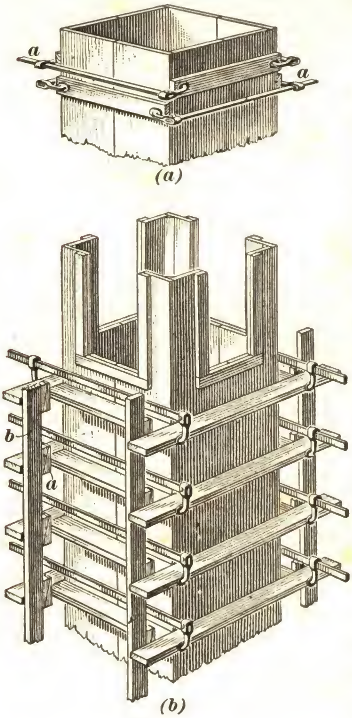


Fig. 68

153. Forms for Flat-Slab Floors.—To mold a flat-slab floor, a horizontal platform or floor at a proper height is required. Such a platform is usually made of planks, as shown in Fig. 69 at *a,* though metal plates are often used to advantage. The platform *a* is supported upon *stringers b,* which are planks set on edge and spaced usually from 4 to 6 feet apart, depending upon the weight to be carried and the size of the planks obtainable. The stringers are supported upon uprights *c* called *props* or *shores.* These are usually 4″×6″ timbers placed from 4 to 6 feet apart in rows. The stringers are nailed to the uprights and also are supported by blocks *d* nailed to the sides of the uprights. Since the uprights are cut to about the right length, the platform will be approximately at the right height; however, to obtain a fine adjustment and a truly level surface, the uprights are stood upon wedges as shown. These wedges consist of two wedge-shaped pieces of hardwood, and by driving them farther in the platform is raised, and vice versa. The wedges also make it easy to remove the forms, since, by knocking the wedges out,

the forms are released from the concrete and can be taken apart.

A view taken underneath the forms and showing the stringers and shores in place is shown in Fig. 66 in conjunction with the column form previously described.

154. Forms for Beam-and-Slab Floors.—The forms for a beam-and-slab floor construction consist essentially of a platform of planks or boards, which is supported by stringers and posts as described in the preceding article. In addition, it

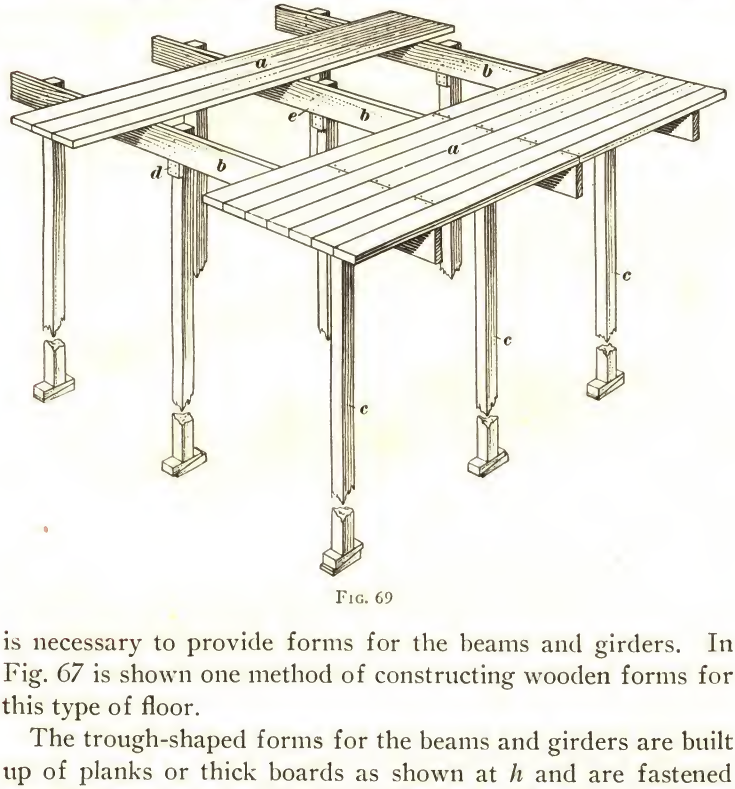


FIG. 69

is necessary to provide forms for the beams and girders. In Fig. 67 is shown one method of constructing wooden forms for this type of floor.

The trough-shaped forms for the beams and girders are built up of planks or thick boards as shown at *h* and are fastened together by means of vertical and horizontal battens *i* and *j*, respectively. To the battens *i* are secured the horizontal timbers *k* on which rest the stringers *l* which support the forms for the slabs.

In this construction the entire weight of the floor is carried by the forms of the beams, which therefore must be made very strong. The ends of the beam forms are set into openings which have been previously made in the column forms, and are thus supported at the ends. When the beams are spaced at such distances between supports that they are likely to sag under the load of the wet concrete, intermediate supports in the form of posts must be used. The posts *m* are made of either 4″×4″ or 4″×6″ timbers with crosspieces *n* at the top and braces *o*, which are secured to the crosspieces and posts to make a rigid support. Blocks *p* are placed on each side of the

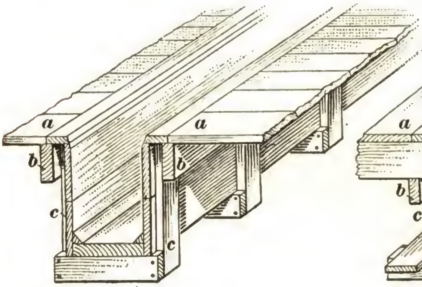


FIG. 70

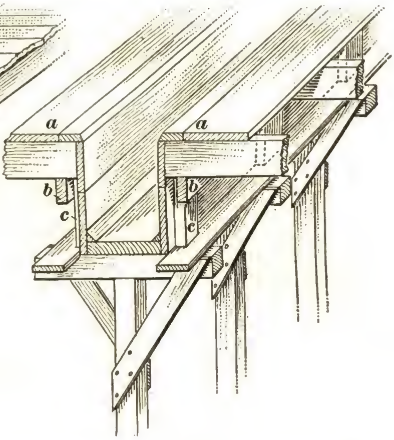


FIG. 71

beam forms and secured to the cross timbers to prevent the form from spreading when the concrete is poured. Wedges are usually placed under the posts as shown, to support the beams and to permit of adjustment.

155. Forms for concrete columns and beams require to remain in place for a longer period of time than forms for floors, because the columns and girders contain greater masses of concrete and consequently require more time for hardening. To permit the removal of the forms for the floor slabs for use in succeeding stories, the forms are so designed that those which support the floor construction may be removed without

disturbing the forms of the beams and columns. The method of construction to permit this is shown in Figs. 70 and 71.

156. In Fig. 70 is shown a section through the form for a beam that runs at right angles to the direction of the planks that are used for forms for the slab. In Fig. 71 is a similar section through a form for a beam that runs parallel with the planks of the slab form. In both of these figures the top of the beam form has pieces of boarding that are beveled on their inner edges, and their outer edges terminate over the centers of the stringers *b*. By this means a joint is formed in

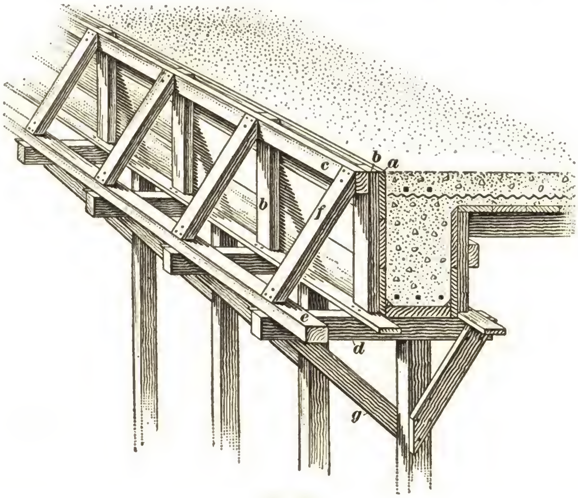


FIG. 72

the flooring around all beams so that when the floor forms are removed the separation between the floor forms and the beam forms will occur at these joints.

157. In Fig. 72 is shown a design of form, brace, and support that is generally used for an outside wall beam or girder of concrete. This form is extended on the outside of the beam to the height of the top of the floor slab, as shown at *a*. The vertical batten *b* is also extended to the same height. A horizontal 2″×4″ continuous timber *c* is secured to these battens. The post support under the girder form is similar to those

previously described. The cross-bar *d*, however, is extended and a horizontal 3″×4″ timber *e* is secured to these cross-bars, and between the timbers *c* and *e* braces *f* are placed every 2 or 3 feet apart to prevent the top of the form from moving when the form is filled with the concrete. The brace *g* supports the extended part of the cross-bar *d* and prevents it from sagging under the pressure on *e*.

An illustration of the use of wooden forms for columns and beams like those shown in Figs. 67 to 72 is given in Fig. 59. It will be seen that each of the column forms has six or seven battens enclosing it and each of the girders has four upright post supports, with the cross-braces at the top. These posts are stiffened by means of a horizontal timber which is placed midway in the height of the posts and securely nailed to them.

158. Treatment of Wooden Forms.—Wooden forms, both for plain and reinforced-concrete construction, are assembled as previously described. After they are set in place and lined up, they are given a coat of soap, crude oil, petroleum, or a similar substance, to prevent the concrete from sticking to the wood. Bolts which tie the forms together are also oiled. Wooden forms should not be put in place too long before filling with the concrete, because the wind and sun dry the wood and cause the boards to warp. When the forms are removed from the concrete they should be carefully cleaned, repaired if needed, oiled, and set up again. If they are not required immediately, they should be stored in a safe place for future use since they represent a very large investment.

159. Inspection of Forms.—While the concrete is being poured into the forms, it is customary to have a competent carpenter examine these forms and their supports, from time to time, in order to detect any weakness or deflection before it becomes too great to rectify. Any holes and defective joints in the forms should be plugged immediately when discovered.

160. Removal of Forms.—The order of procedure in the removal of the forms from a concrete construction consisting of floor slabs, beams, and columns is to remove the floor-slab forms first, then the beam and the column forms.

161. To remove the floor forms, such as shown in Fig. 67 at *q*, the floor stringers that run parallel with the beams, as shown at *b* in Figs. 70 and 71, must be pried loose from the battens *c*, whereupon the flooring usually drops away from the concrete and the entire floor form is thus removed. If the flooring still adheres to the concrete it is easily pried loose by means of a bar. The removal of the floor forms leaves the beam enclosure and its supports as shown in Fig. 73. This beam form is usually removed at the same time as the column form.

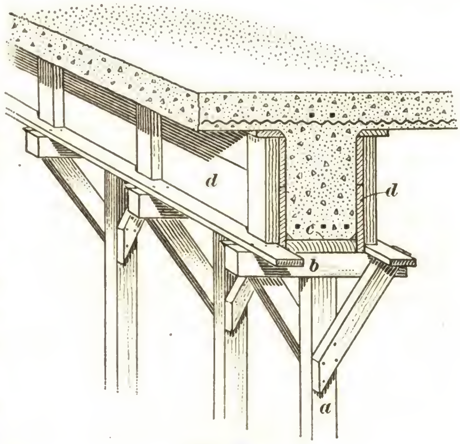


FIG. 73

162. It may be desirable to retain some of the support under the girders and beams for a time, as they are often required to carry a certain amount of load and may not have hardened sufficiently to carry the load without deflecting. The necessary support may be secured by retaining the posts *a*, Fig. 73, the cross-bar *b*, and the bottom part *c* of the form of the girder. The side pieces *d* may be removed, so that the air may reach the concrete and facilitate its hardening.

163. When the Forms May Be Removed.—There is no definite rule for the length of time which must elapse after concreting before the forms can be removed. The time depends upon the weather, the kind of cement and aggregate, the span of construction, and the thickness of the slab or mass of concrete. Only a competent and experienced person can judge when the proper time has arrived. Under favorable conditions the time may vary from one week, for slabs, to three weeks or a month for beams, girders, and columns. Some cities have

building codes containing a schedule indicating the minimum lengths of time that forms must remain in place after the concrete has been poured. This is based on the concrete having been placed when the temperature was above 32° F. If concrete is placed when the temperature is below 32° F., a special permit must be secured in some cities before the forms may be removed.

CONCRETE-BLOCK CONSTRUCTION

SHAPES OF BLOCKS

164. Definition.—A **concrete block** is a building unit formed of concrete molded into a convenient form. The common shape of a concrete block is such that its exposed surface is a rectangle. The block may extend through the wall, or it may not. In every case, provision is made for an air space in the wall, and the means by which this is accomplished vary widely and are covered by many patents. The purpose of this air space is to prevent heat, cold, and dampness from penetrating the wall.

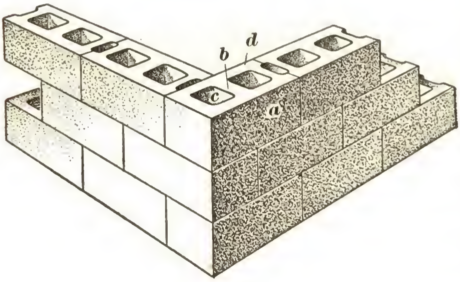


Fig. 74

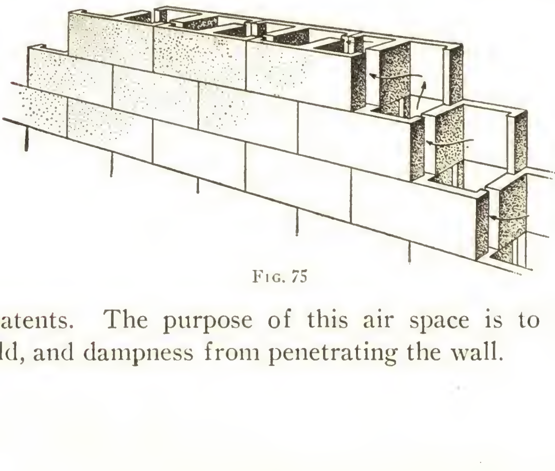


Fig. 75

165. One-Piece Blocks.—Blocks that extend through a wall are termed *one-piece* blocks. The outer part is called the *face section;* the inner part, the *back section;* and the partitions

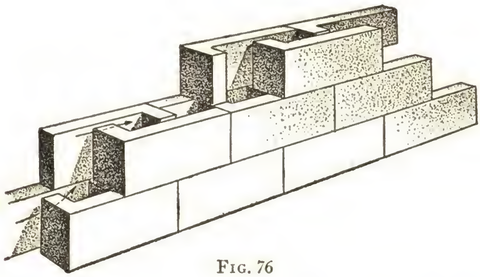


FIG. 76

that unite the face section to the back, the *webs,* or *withes.* All such blocks are termed *hollow blocks.*

Fig. 74 shows the general form of a one-piece hollow block. The face section of this block is shown at *a*; the web, at *b*; the hollow spaces, at *c*; and the back section at *d*. The spaces in one block connect with those in the block above and the one below, forming a continuous air space from the top to the

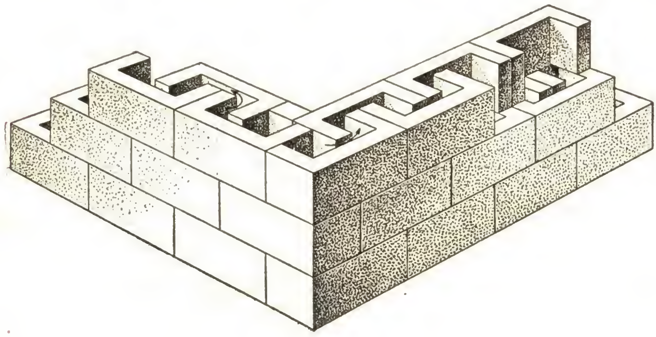


FIG. 77

bottom of the wall. Different types of one-piece blocks differ, however, in this arrangement.

In hollow blocks, the number of webs on each block may vary from two to four or more; three is the common number, as it affords two or, as in Fig. 74, three, hollow spaces.

166. Two-Piece Blocks.—Blocks in which the face section and back section constitute two separate parts are known

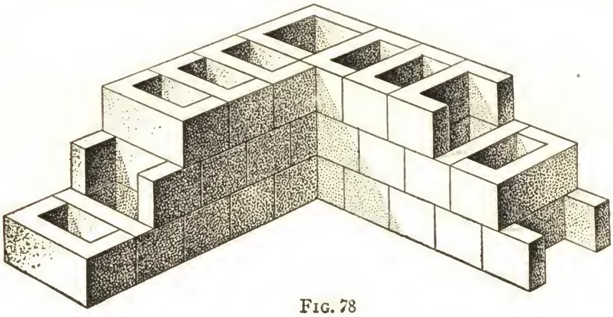


Fig. 78

as **two-piece blocks.** These blocks are of various forms and are often patented. The more common forms are designated as **T** shaped, shown in Fig. 75; **L** shaped, in Fig. 76, and **U** shaped, in Fig. 77, because their general outlines conform to the shape of these letters.

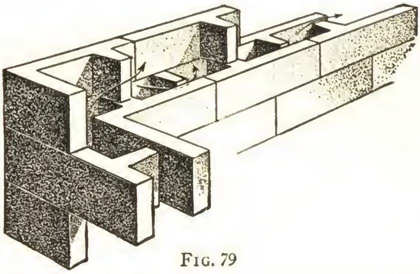


Fig. 79

These blocks are placed so as to provide as large air spaces as possible between the outer and inner surfaces of the wall.

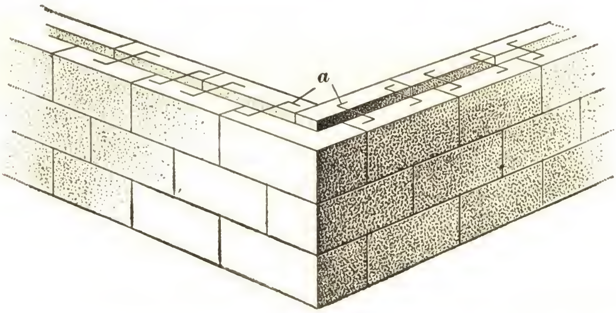


Fig. 80

Fig. 78 shows a wall that is made up of **U**-shaped blocks laid crosswise, instead of lengthwise, as in Fig. 77.

The type of block used in the wall shown in Fig. 79 is an unsymmetrical form of the **T**-shaped block.

In laying two-piece walls, the blocks on the back of the wall break joints with those on the front, so that the only joints

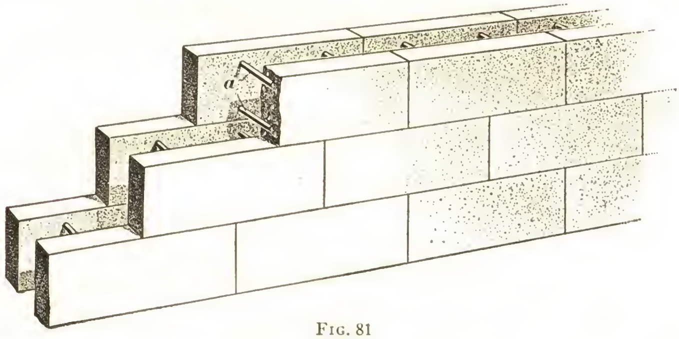


FIG. 81

extending through the wall are the horizontal ones between the courses.

In Fig. 80 is shown a form of block in which two slabs, one forming the face and the other the back, are joined by metal ties *a* laid in mortar on top of each course. This gives the general effect of a one-piece block, the only difference being a

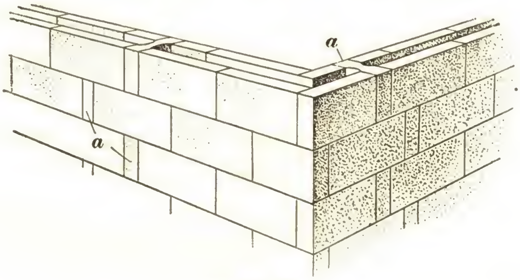


FIG. 82

continuous air space throughout the wall, as the transverse webs are omitted and the metal ties perform their function.

Another type of two-piece block that produces a continuous air space is shown in Fig. 81. Each pair of blocks is permanently united by means of four rods *a*, that are embedded during the casting process.

169. Other types of machines are those known as *side-face* machines, because the face plate is on one side of the mold; and *press-block* machines, which press the concrete into the form of blocks. Many of these machines have interchangeable face plates whereby the exposed face of the block can be finished in different designs such as plain face, rock face, imitation ashlar, tooled face, and other finishes that are used in cut stone work.

SURFACE FINISHES FOR BLOCKS

170. Concrete blocks may have surface finishes similar to those described for walls of poured or cast concrete. Some

FIG. 85

additional finishes of an attractive character are also possible because of the manner in which the block is made.

For blocks that are to be veneered with a special mixture of aggregate, the mixture is placed in the form first and the rough

concrete is deposited on top of it. The treatment of the block after it is taken from the form may be by any of the processes described for walls.

171. There is a form of veneer for the blocks which presents a face consisting largely of actual stone that is very pleasing. To secure this form of surface, a layer of sand about $\frac{1}{2}$ inch in thickness is first spread over the bottom of the form. Upon this sand are placed thin pieces, or chips, of granite having irregular shapes and sizes, these pieces being usually split by hand from larger pieces. They should be laid in the form as close together as possible without overlapping. A rich mortar consisting of one part cement and one part sand, mixed very wet, is then poured into the forms, sufficient mortar being used to cover the stones. Immediately after pouring this mortar, the forms are filled with ordinary concrete, and the blocks are left in the forms until the following day. They are then removed, stored, and allowed to dry slowly, as is customary with ordinary concrete blocks, and without further treatment are ready to be placed in the wall. A wall formed of this style of concrete blocks is shown in Fig. 85. The joints between the blocks may be pointed with a colored mortar and finished in the form of a raised bead.

SIZE AND WEIGHT OF BLOCKS

172. Size.—The size of a concrete block from the face section to the back is variable, because the width is regulated by the required thickness of wall. This dimension can be changed by lengthening or shortening the connecting webs. It is customary, however, in thicker walls to make some variation in the thickness of the face section and the back of the blocks. In this way a larger bearing surface is afforded and increased resistance to unequal expansion is obtained in case of excessive heating of one side of the wall. On the other hand, the decrease in thickness of face and the back sections in narrow walls carrying light weights not only serves to increase the insulation afforded by the interior air space, but also effects

some saving of material. The thickness of walls as customarily specified are as given in Table III.

173. The length and height of the blocks are determined by three factors: (1) Facility in handling and laying; (2) preservation of a multiple system; and (3) appearance in the completed wall.

The general tendency has been to make as large blocks as possible in order to reduce the manufacturing cost per square foot of wall. The expense of handling large blocks is, however, objectionable. Consequently, blocks 16 inches in length are the most common size, being light enough in weight to be handled by one man.

TABLE III

THICKNESS OF WALLS FOR BUILDINGS OF VARIOUS HEIGHTS

(*Thickness of Partitions, 4 to 6 Inches*)

Height of Building	Thickness of Wall, Inches				
	Basement	First Story	Second Story	Third Story	Fourth Story
One story	12–15	8–10			
Two stories	15–17	10–12	8–10		
Three stories	17–20	12–15	10–12	8–10	
Four stories	20–22	15–17	12–15	10–12	8–10

The heights of the courses are generally 4 inches, 8 inches, or 12 inches, which simplifies construction.

174. Weight.—The weight of a concrete block is determined by its composition, its size, and its percentage of air space.

Weight is important because of the cost of handling and because of the load on the lower courses and the foundation. In general, the aim should be to keep the weight low enough in one-piece blocks so that one man can handle a block on the wall. When these weights are exceeded, it usually means paying an extra man to assist in handling the blocks, and he is necessarily idle part of his time.